Monsoon workshop

Decadal to long-term variability of the climate over the South China Sea inferred from measurement and proxy data

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Outline

- **Background.**
- **Decadal to interdecadal variability of the climate over the South China Sea.**
- **Regime shift of the climate over the South China Sea**
- **Millennium scale variability of the climate over the South China Sea**
- **Conclusion**

Corals

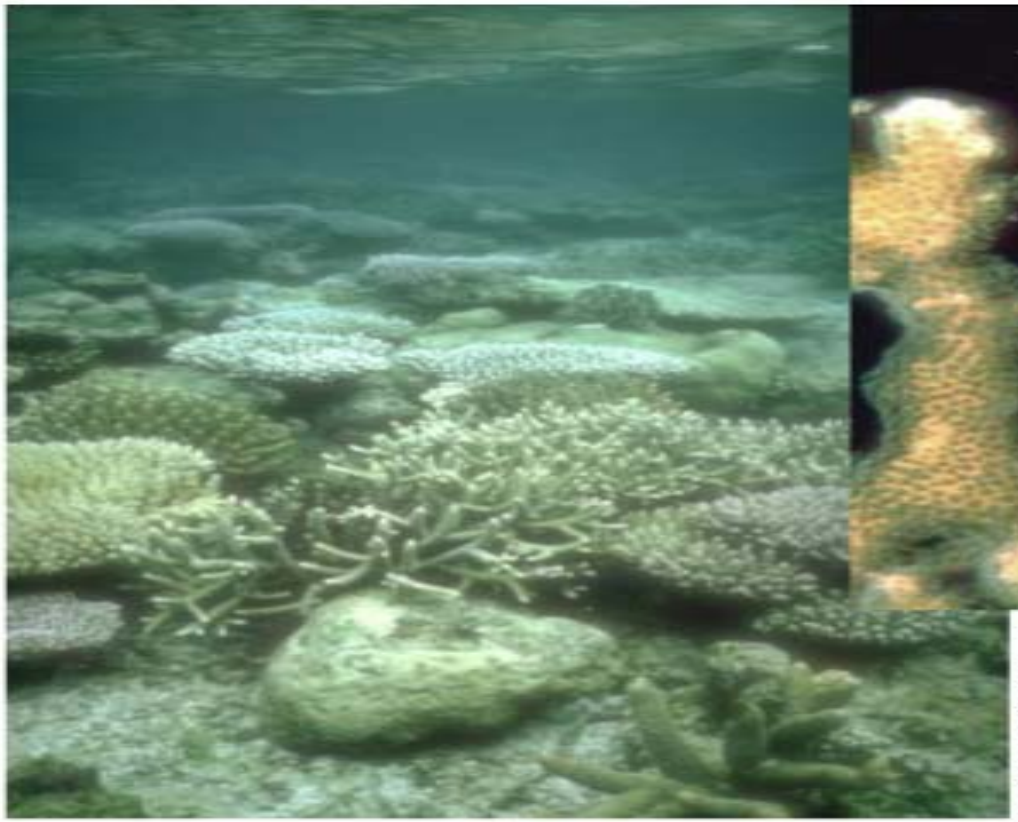


Photo: Reef flat, Palau, J. Wellington

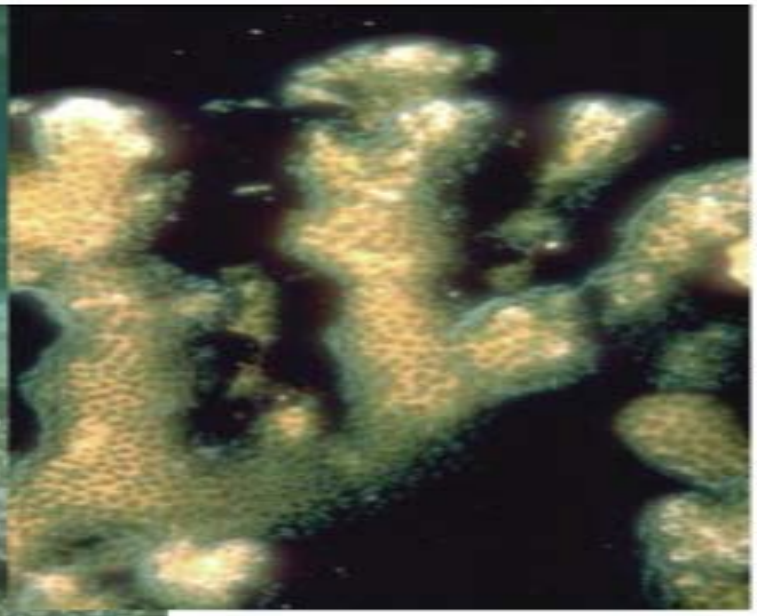
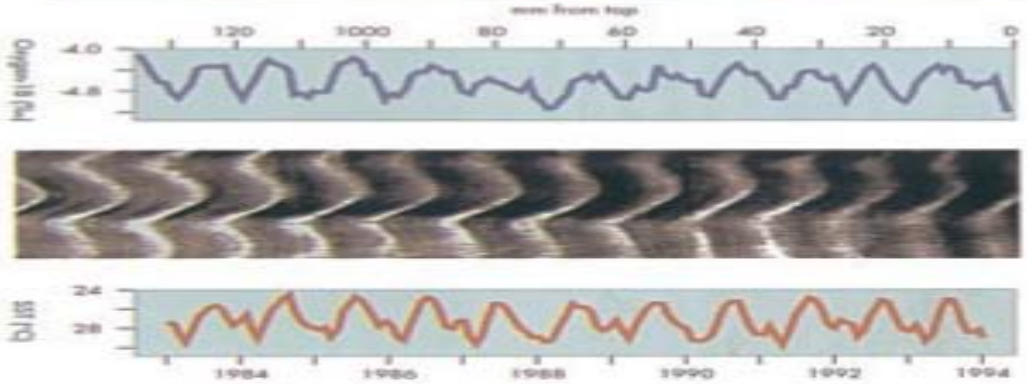


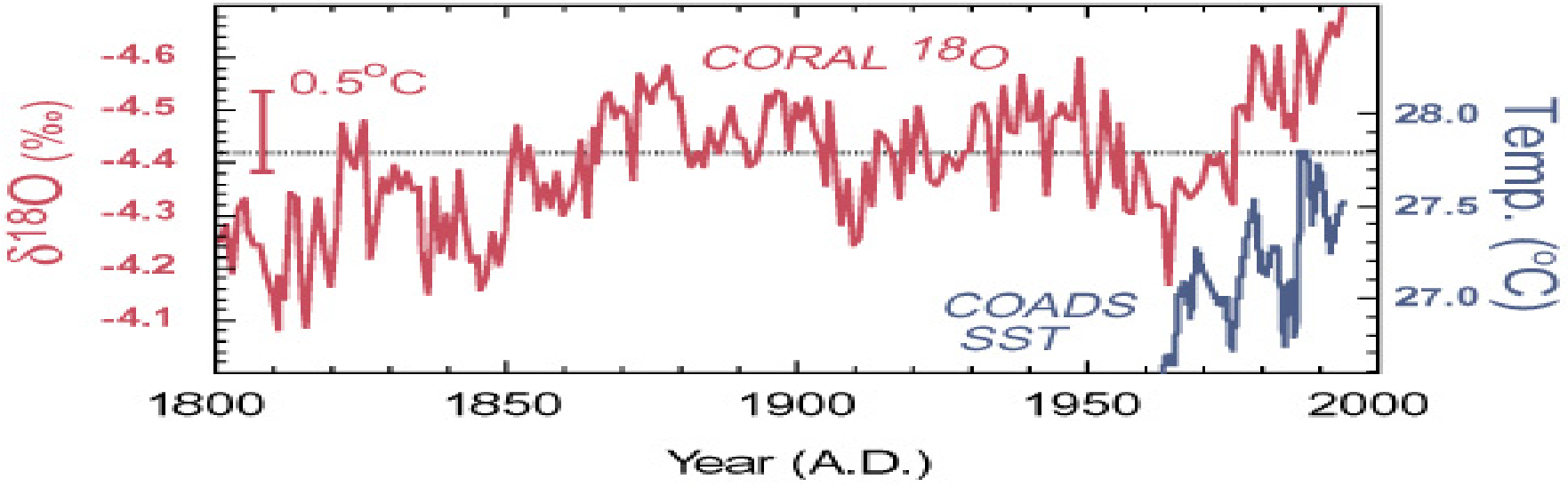
Photo: Branching coral, Panama, J. Wellington



This graph shows how closely Oxygen-18 isotope concentrations in annually banded corals follow the seasonal changes in Sea Surface Temperature (SST). From this type of calibrated measurement it is possible to reconstruct the past periodicity of ENSO events. In some cases precipitation information can also be recovered from banded corals. The existence of fossil corals provides a potential record much longer than the lifespan of individual coral species (R. Dunbar and J. Cole, pers. communication).

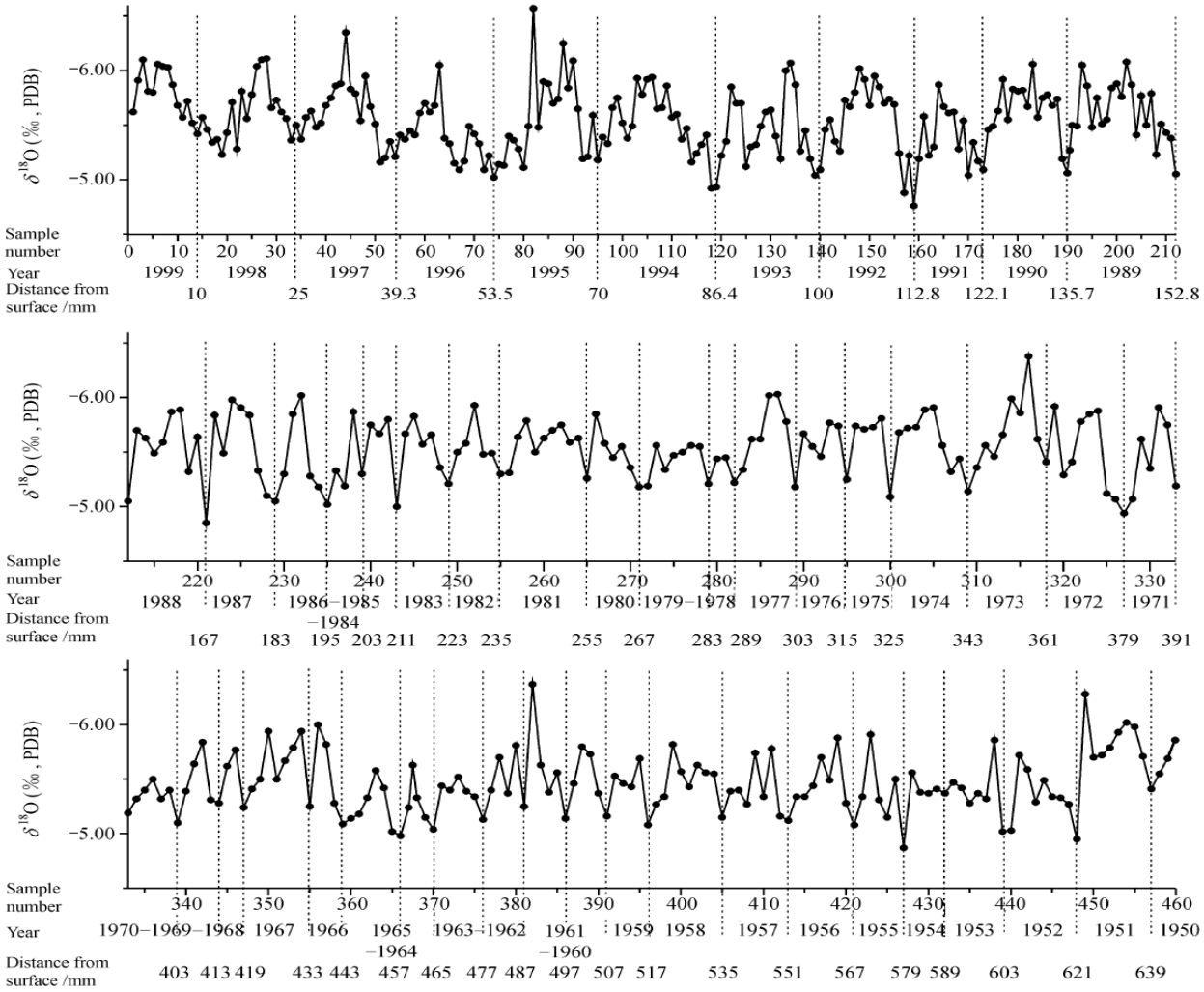
Corals

Coral reefs with annual growth bands are strategically located throughout the tropical oceans. Reconstructions of both precipitation and sea surface temperature can be extracted, providing a record of tropical climate variability far longer than the instrumental record. As such they can improve understanding of natural tropical (e.g. ENSO) variability. One of the indications from these archives is that the mode of variability of the last few decades has not persisted over longer intervals.

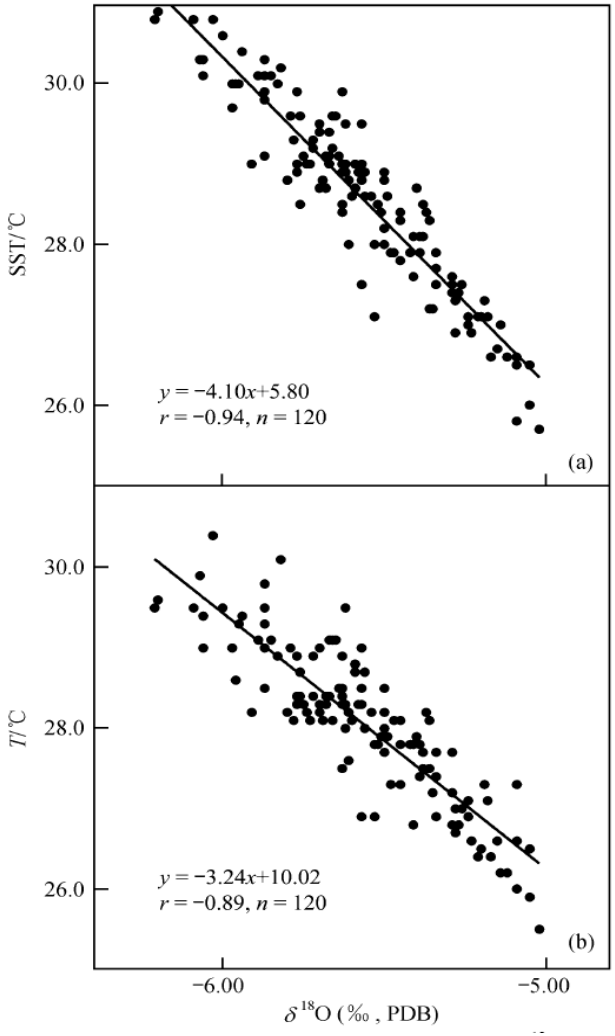


A Long term record of Oxygen-18 isotope data from corals in the Western Indian Ocean off Kenya compared against the COADS SST record for recent years. Source: R. Dunbar and J. Cole, unpublished data.

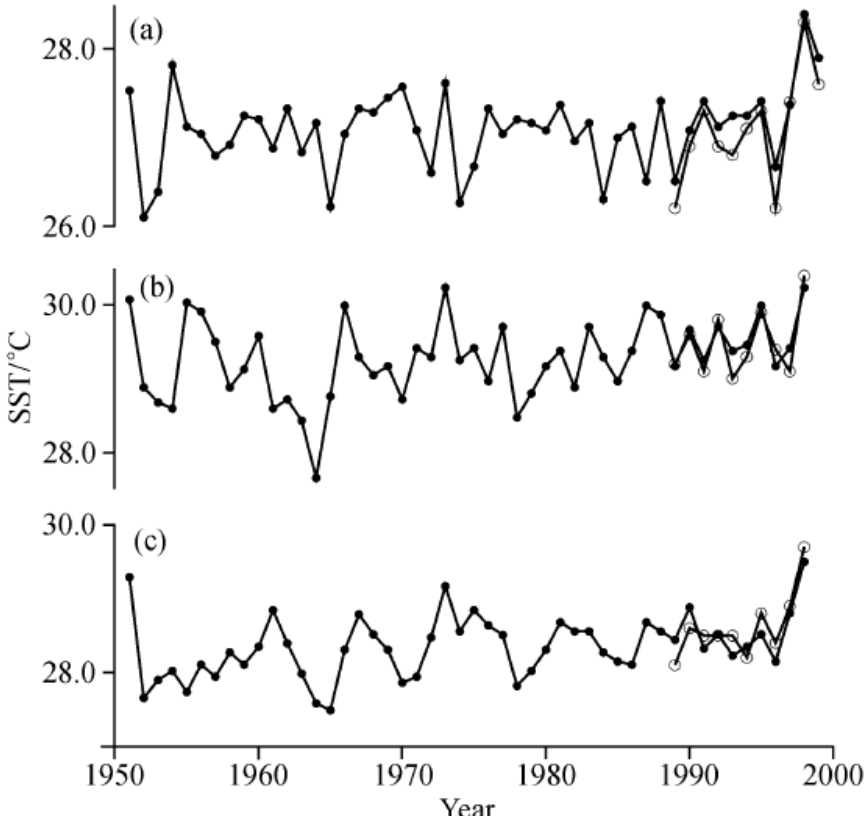
The YSL-12 $\delta^{18}O$ and the corresponding year from 1950 to 1999



The correlationship between the monthly coral $\delta^{18}O$ and the snstrumental SST and air temperature (t).

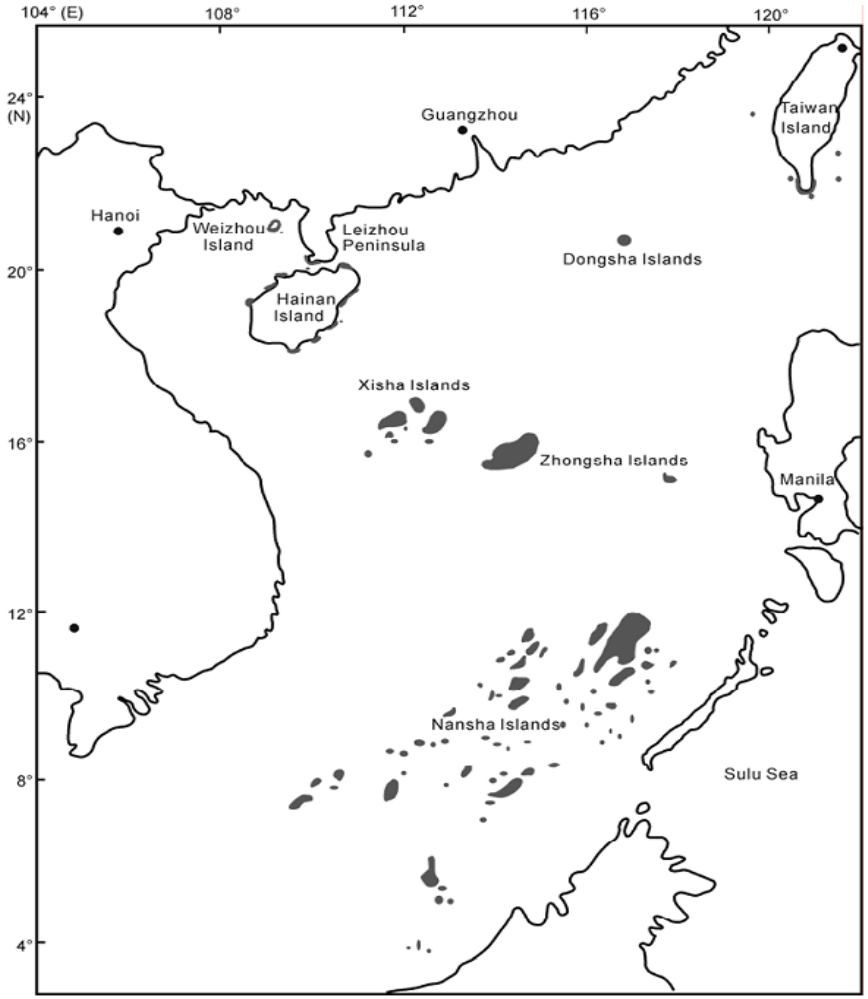


(a)$\delta^{18}O$ and SST; (b) $\delta^{18}O$ and t



(a) Winter SST; (b) spring SST; (c) mean annual SST

The distribution of the coral reefs in the SCS



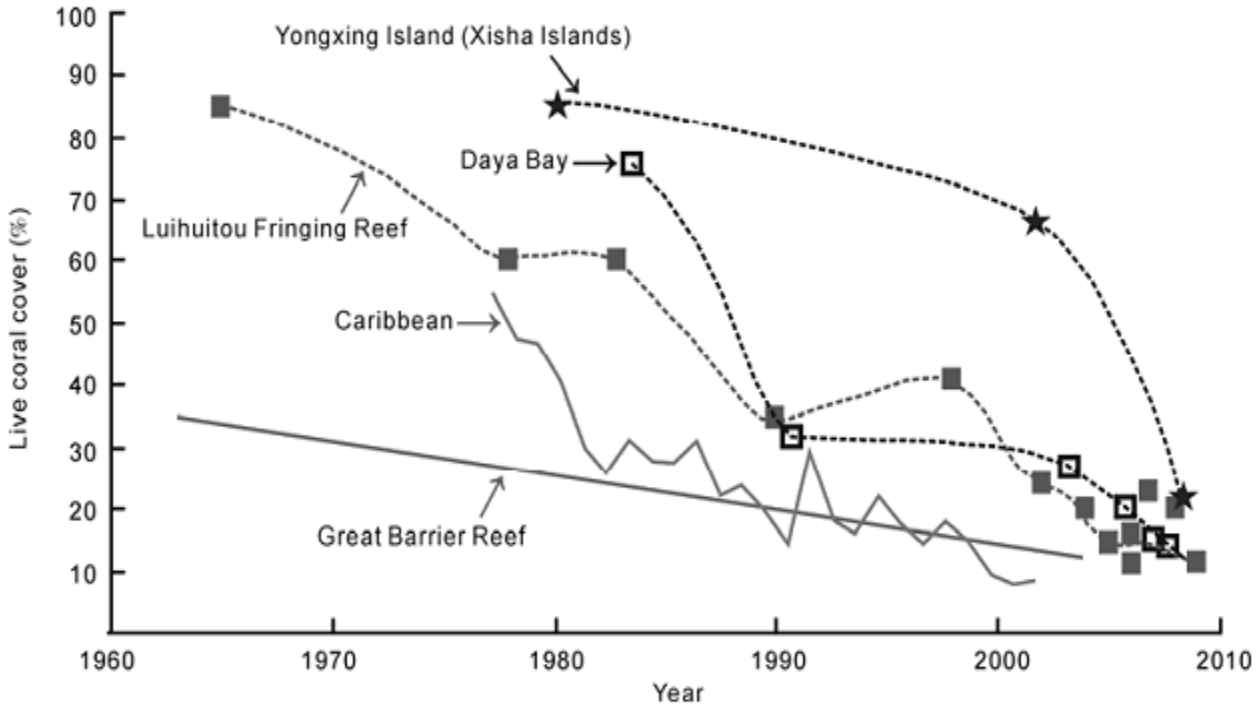
(Yu et al., Sci China Earth Sci, 2012)

Coral reefs in the SCS can be divided into the following seven geographical regions:

- South China coast and its offshore islands.
- Hainan Island and its offshore islands.
- Taiwan Island and its offshore islands.
- Dongsha islands.
- Zhongsha Islands.
- Xisha Islands.
- Nansha Islands.

The shallow-water (<50 m) modern coral reef area in the SCS approximates 8000 km^2.

The ecological status of the coral reefs in the SCS



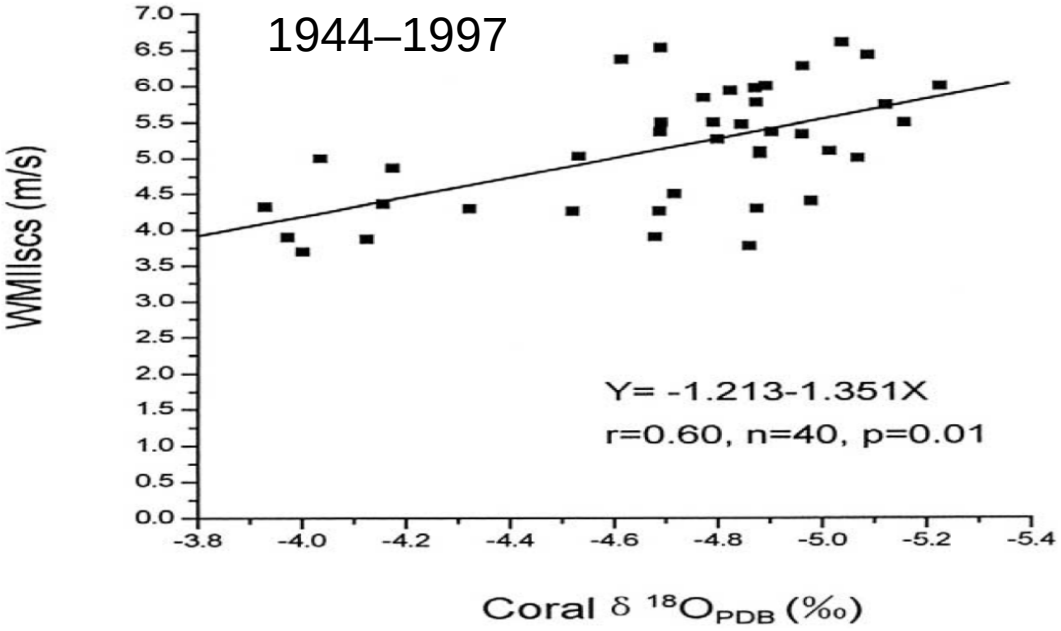
The coral reefs of the SCS have suffered a dramatic decline over the past 50 years:

- Live coral cover in Daya Bay (northern SCS) declined from 76.6% to only 15.3% between 1983/1984 and 2008;
- Luhuitou fringing reef (Hainan Island, northern SCS) coral cover decreased from ~80%–90% to ~12% between 1960 and 2009 ;
- In Yongxing Island (the Xisha Islands, central SCS) decreased from 90% to ~10% between 1980 and 2008.

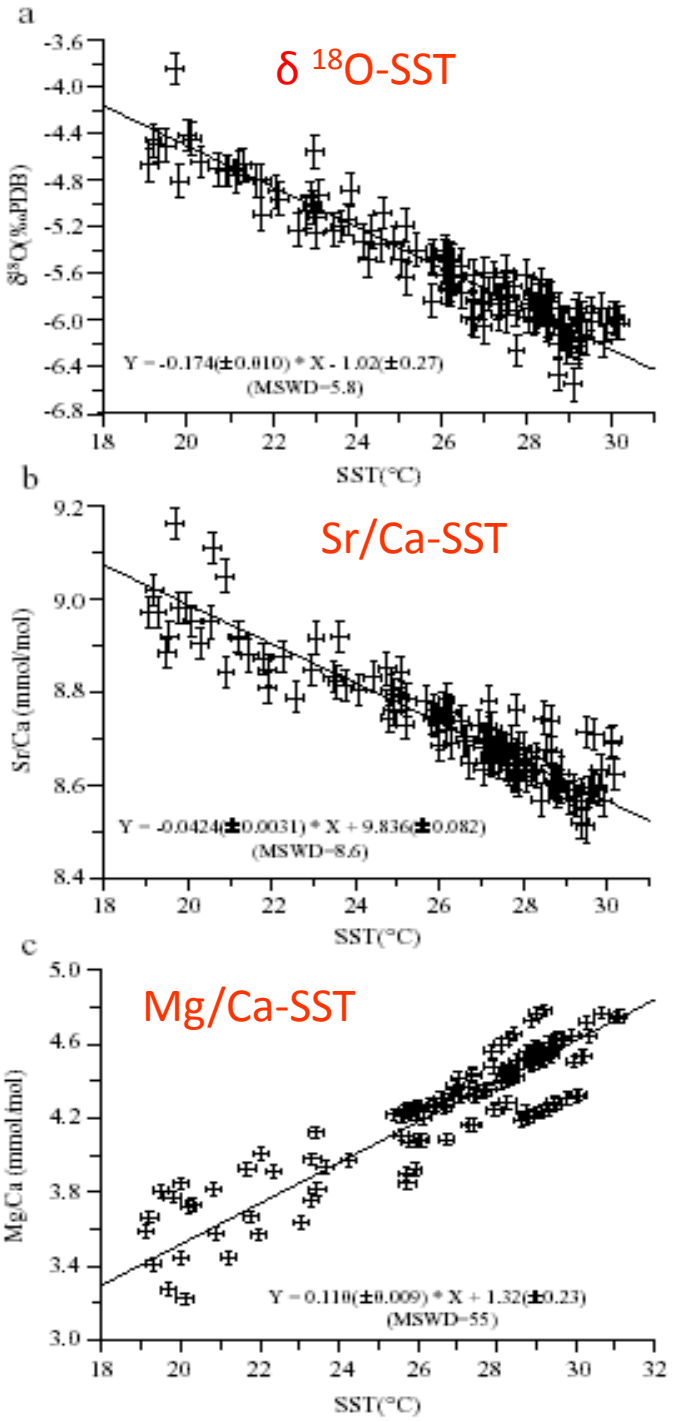
(Yu et al., Sci China Earth Sci, 2012)

Coral & SST & monsoon

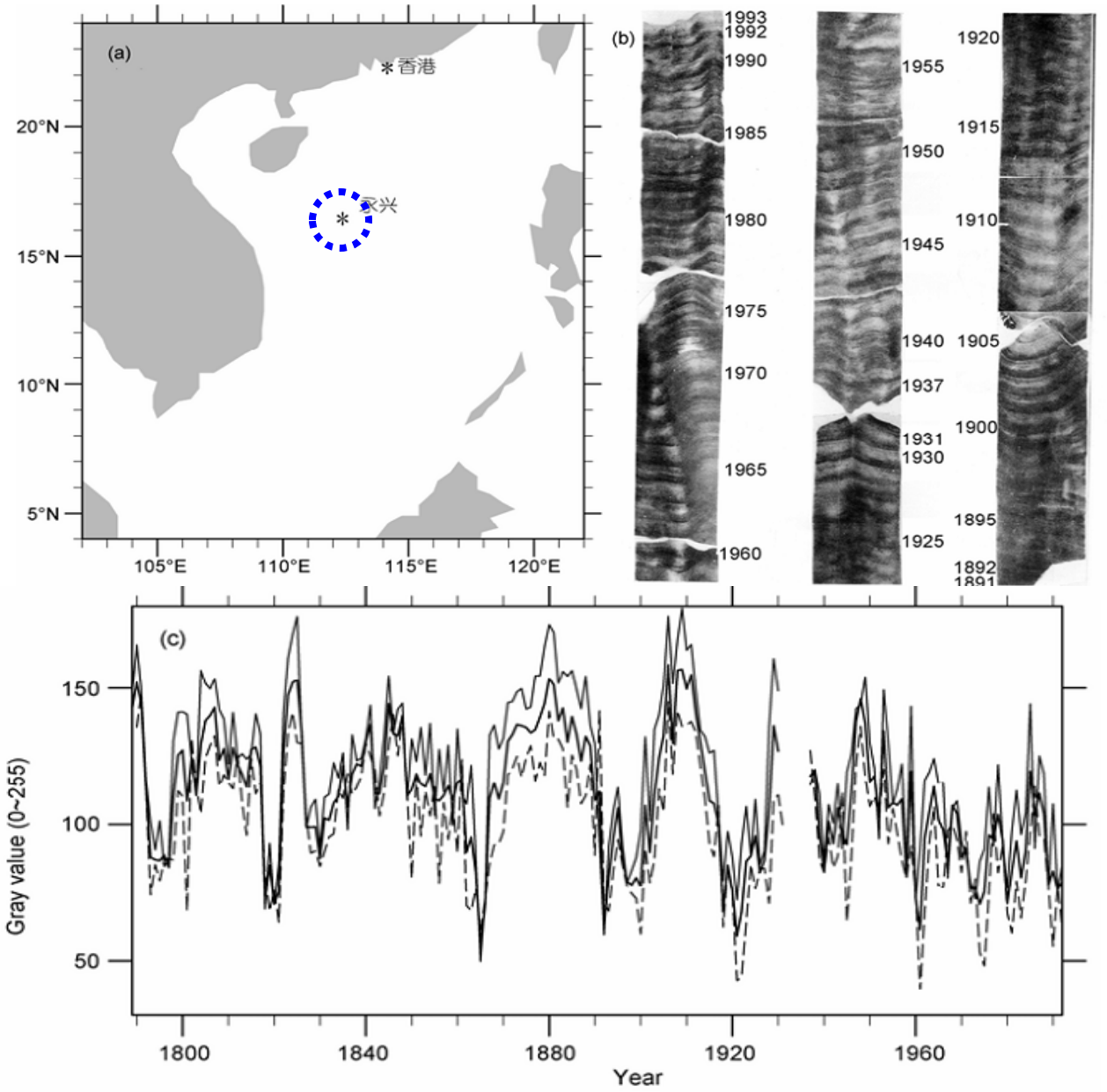
- Coral geochemical proxies ($\delta^{18}O$, Sr/Ca, Mg/Ca), at monthly resolution, are highly correlated with SST.
- Winter and summer SSTs indicate the intensities of EAWM and EASM, respectively.



(Yu et al., 2001; 2005; Peng et al., 2003)



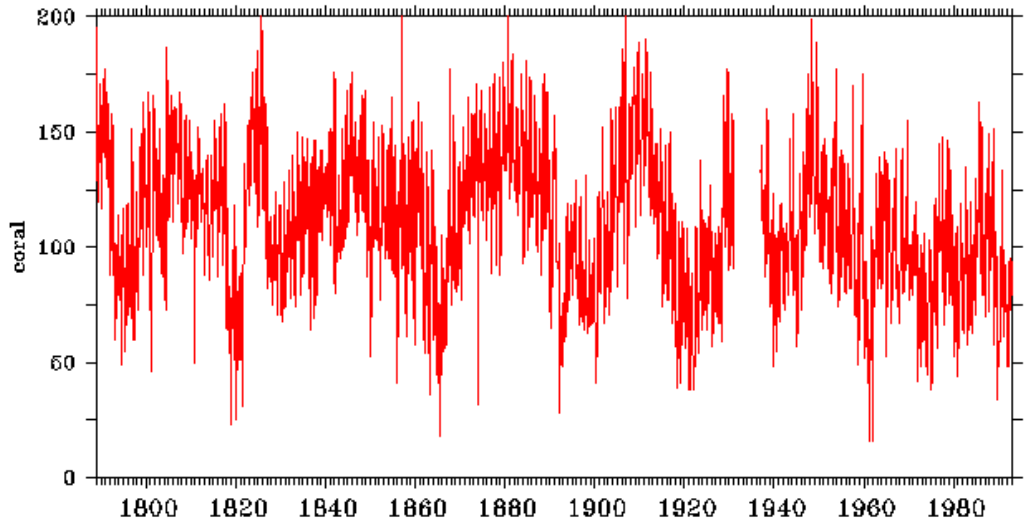
Secular trend of coral skeletal density in the SCS



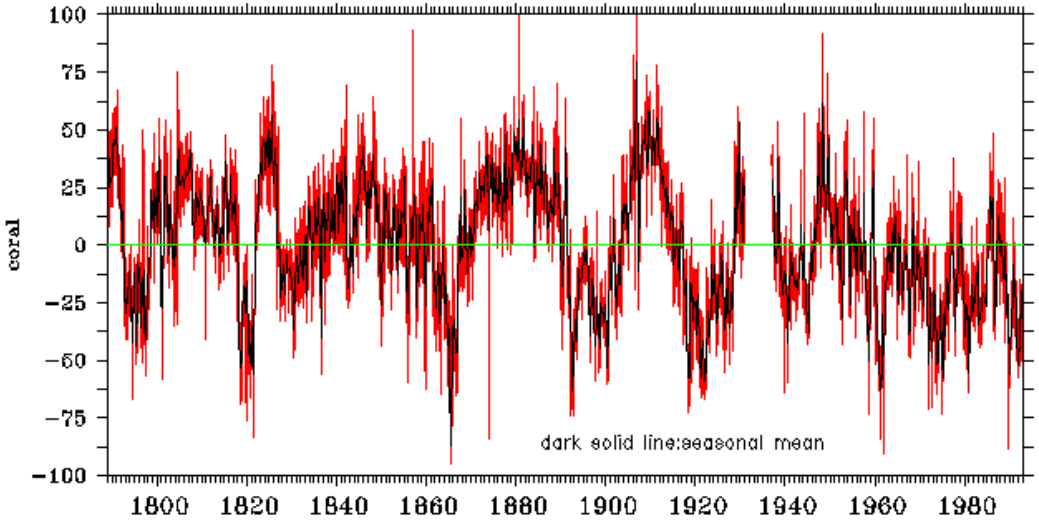
- A colony of Porites lutea growing on the Yongxing Island was drilled in June 1994.
- The coral had grown at a depth of 10 m, and the colony was about 2.5 m in height.
- This coral core spans the period of 1789−1992, with a data gap over 1931−1936.

(Wang et al., 2010;)

Coral time series (1789-1992)

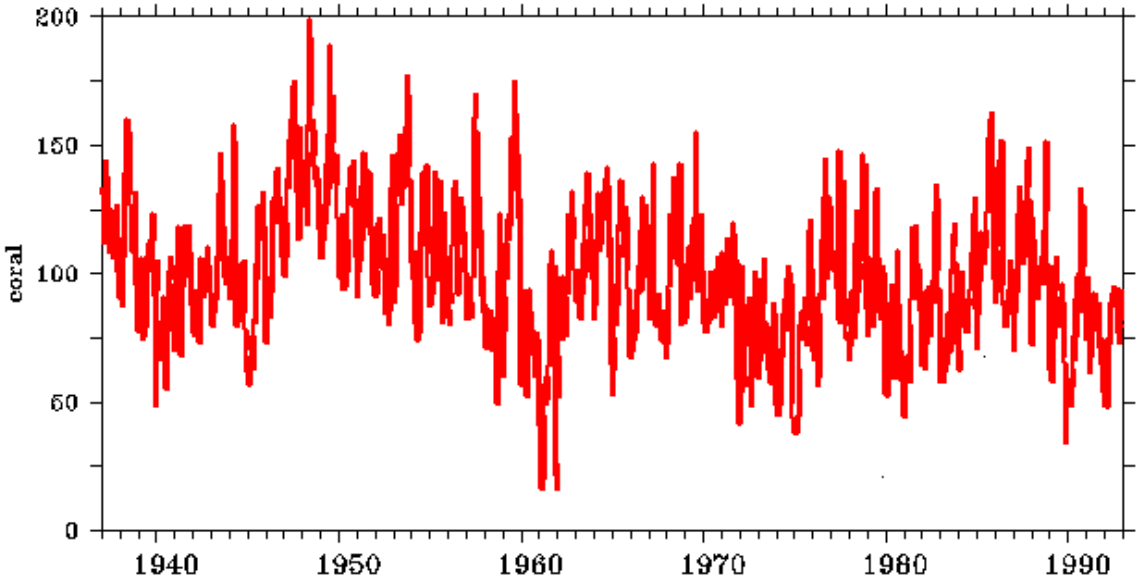


Time series of coral during period for 1789-1992(50samples/year).

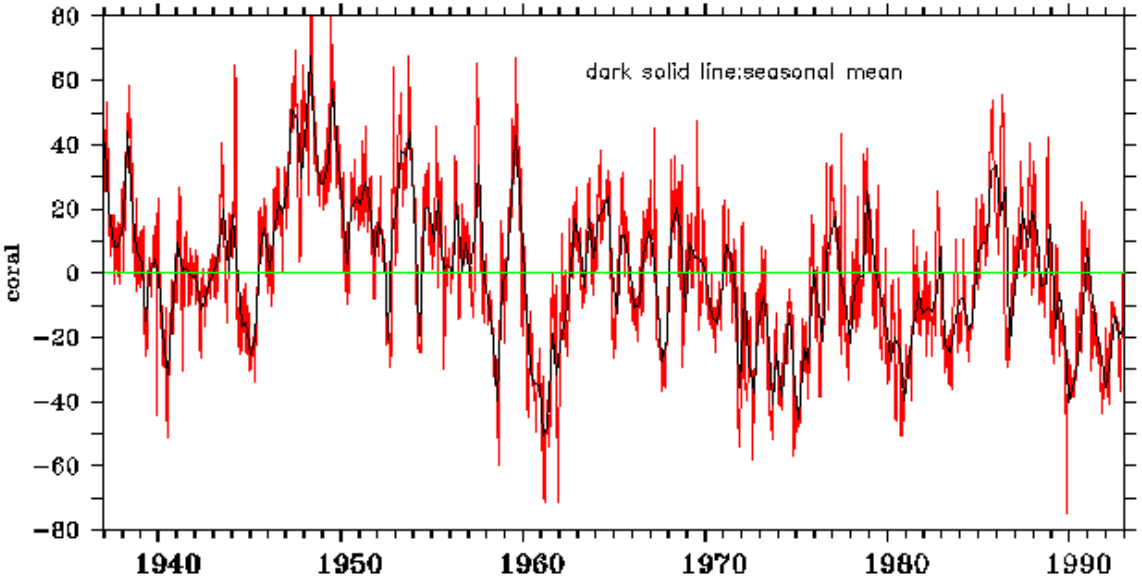


Time series of coral anomalies for 1789-1992(50samples/year).

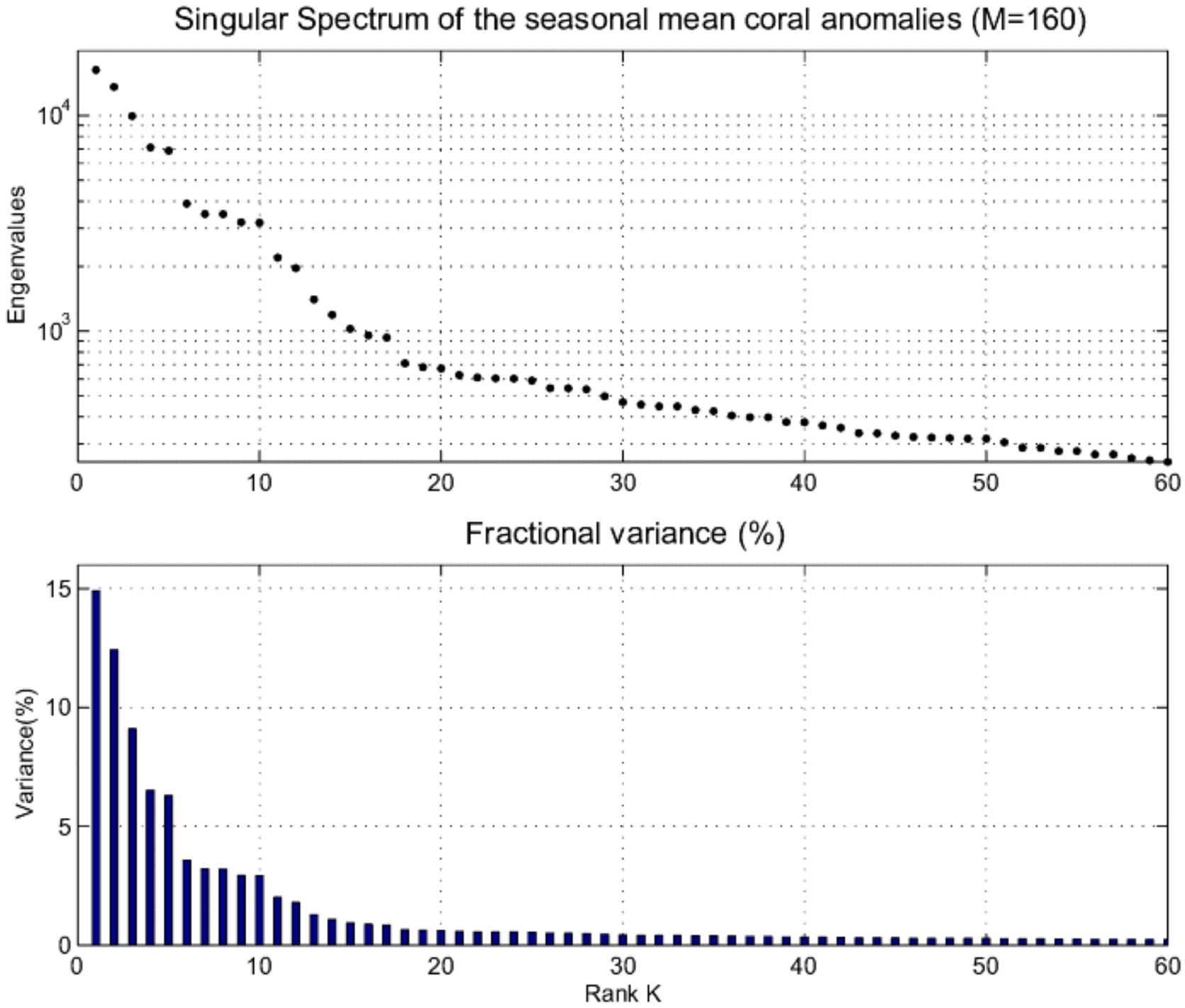
Coral time series (1937-1992)



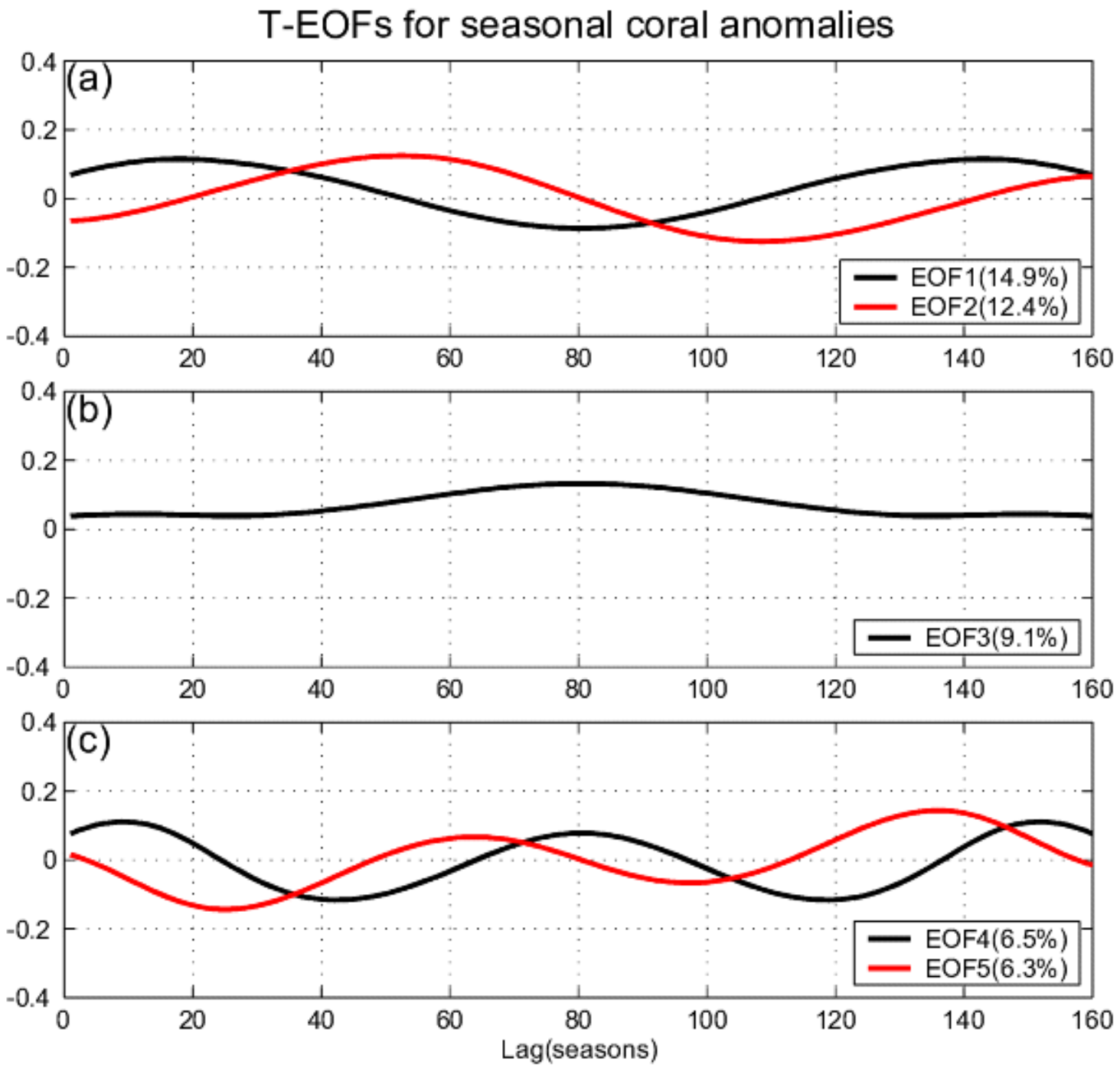
Time series of coral during period for 1937–1992(50samples/year).



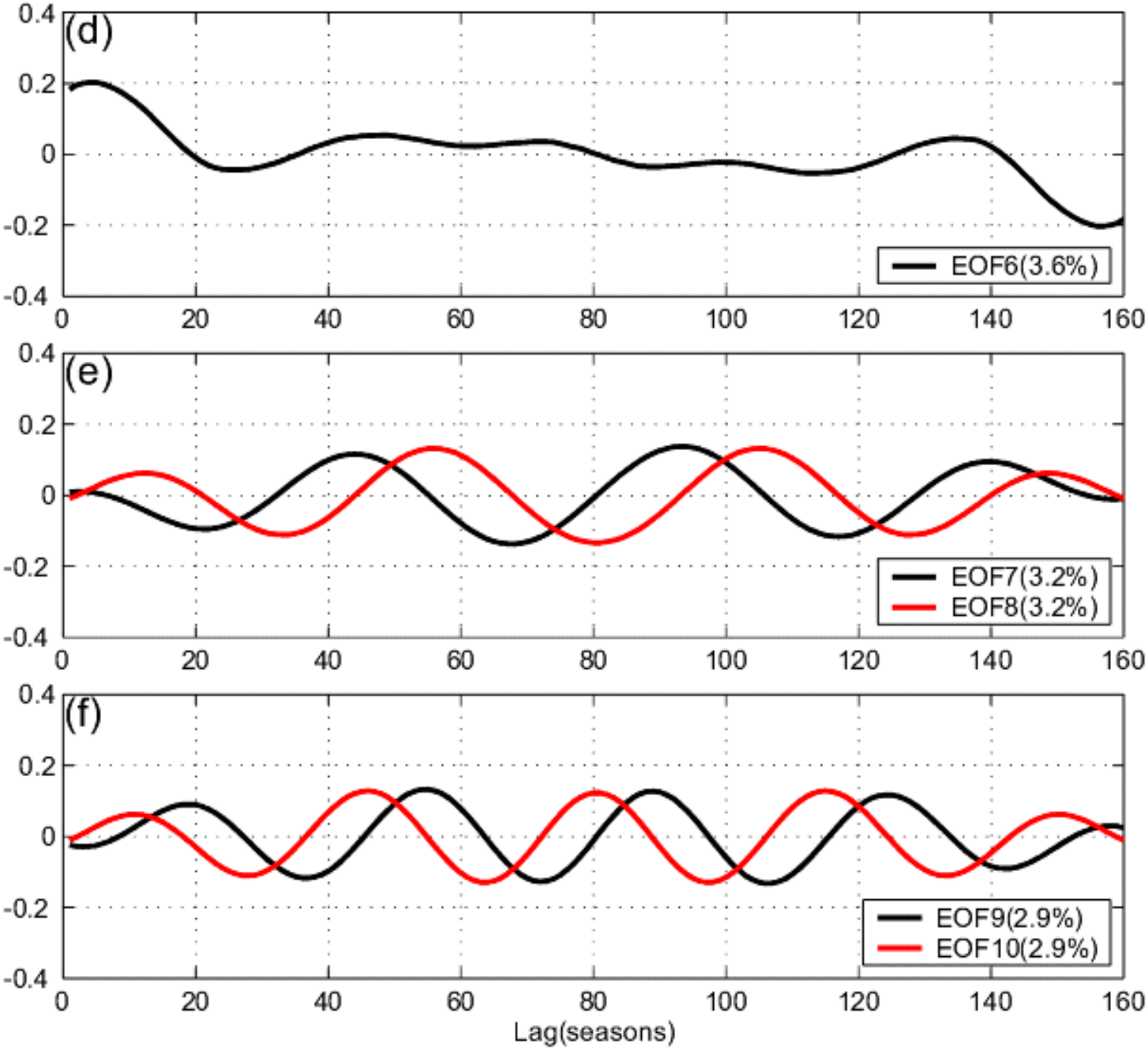
Time series of coral anomalies for 1937–1992(50samples/year).

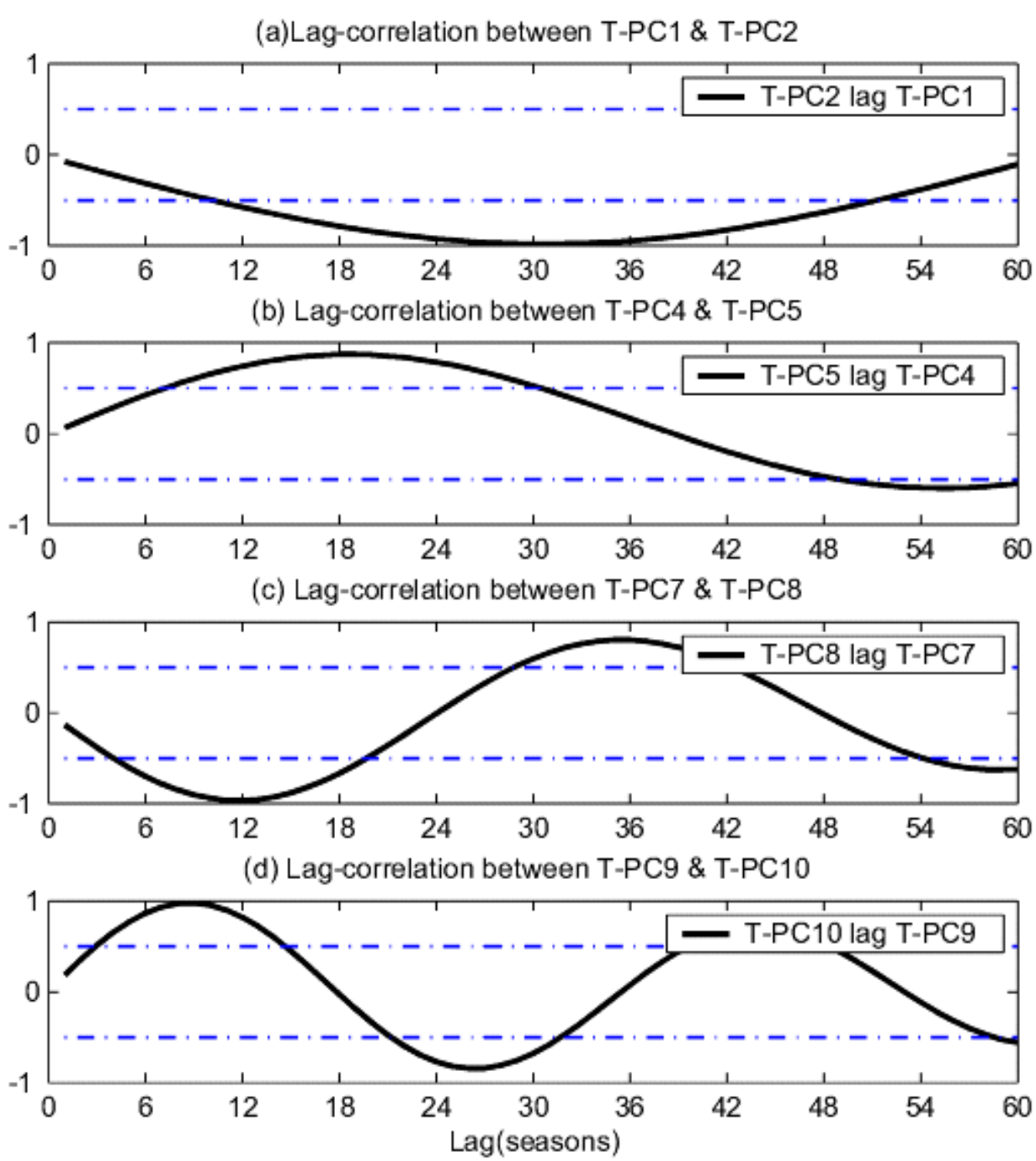

Singular Spectrum of the seasonal mean coral anomalies (M=160)
Engenvalues
10^4
10^3
0
10
20
30
40
50
60
Fractional variance (%)
Variance(%)
15
10
5
0
0
10
20
30
40
50
60
Rank K

T-

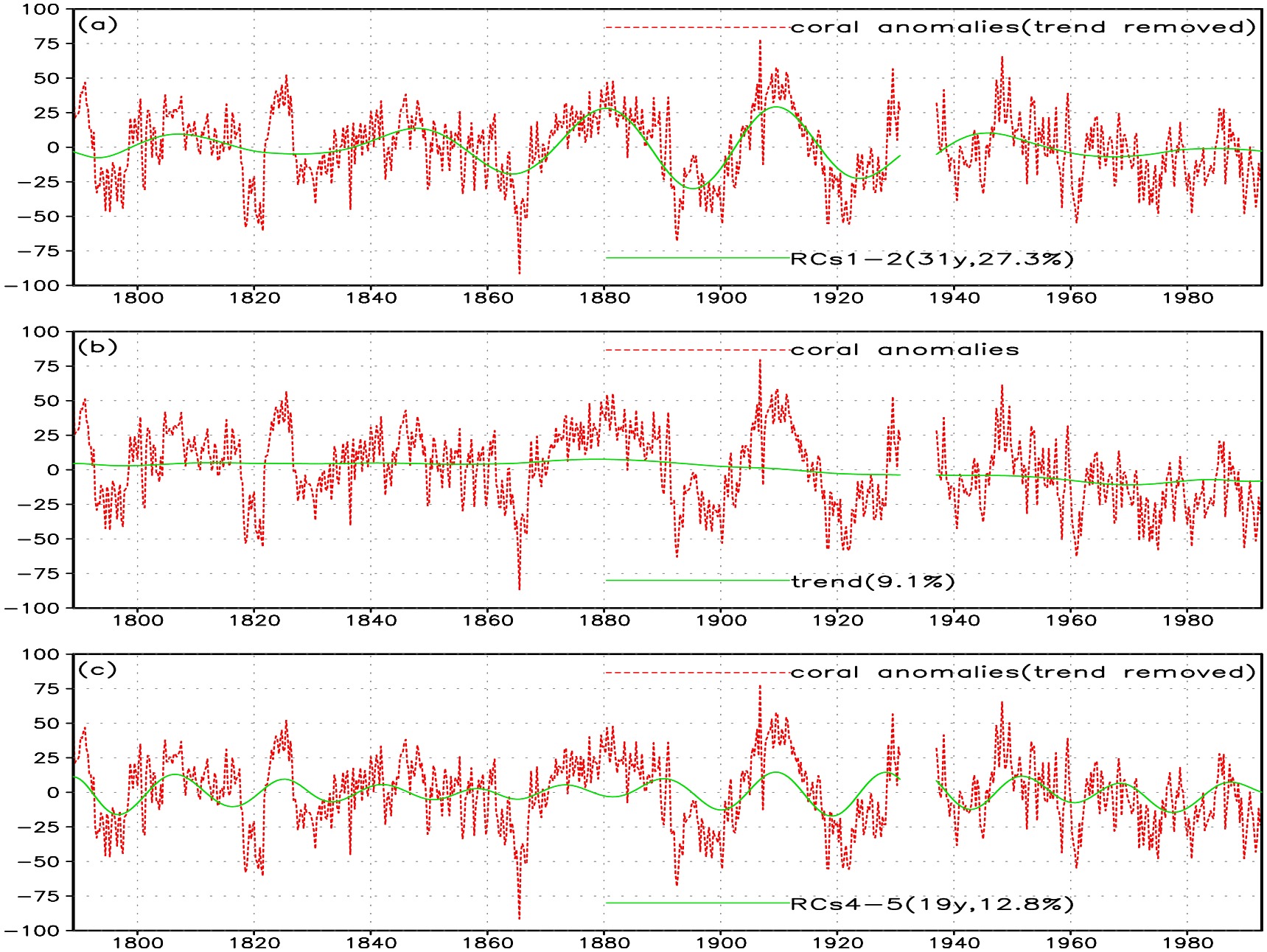

T-EOFs for seasonal coral anomalies
(a)
EOF1(14.9%)
EOF2(12.4%)
(b)
EOF3(9.1%)
(c)
EOF4(6.5%)
EOF5(6.3%)
0.4
0.2
0
-0.2
-0.4
0
20
40
60
80
100
120
140
160
Lag(seasons)

(continued)


(d)
EOF6(3.6%)
(e)
EOF7(3.2%)
EOF8(3.2%)
(f)
EOF9(2.9%)
EOF10(2.9%)
0.4
0.2
0
-0.2
-0.4
0
20
40
60
80
100
120
140
160
Lag(seasons)

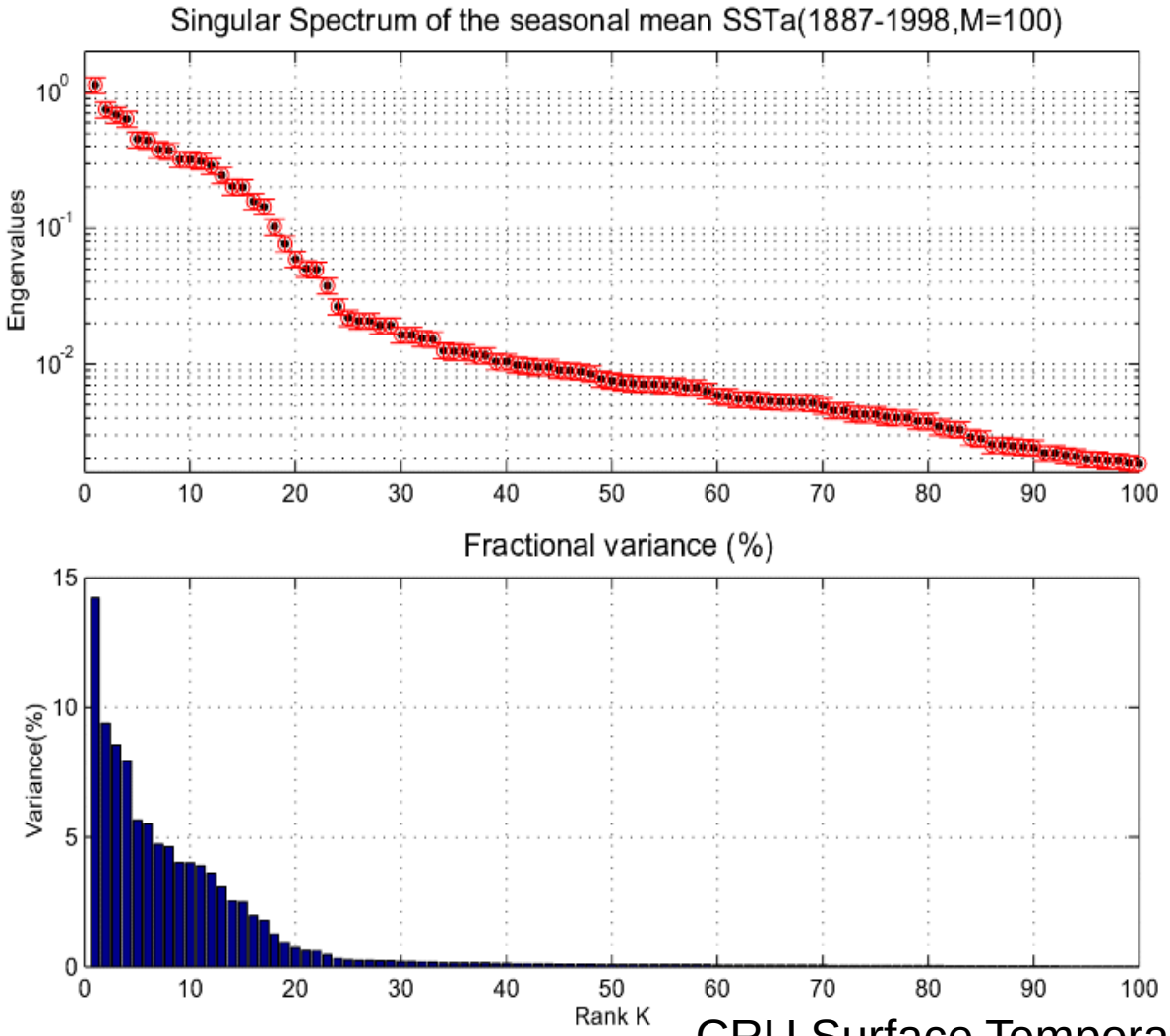

(a)Lag-correlation between T-PC1 & T-PC2
T-PC2 lag T-PC1
(b) Lag-correlation between T-PC4 & T-PC5
T-PC5 lag T-PC4
(c) Lag-correlation between T-PC7 & T-PC8
T-PC8 lag T-PC7
(d) Lag-correlation between T-PC9 & T-PC10
T-PC10 lag T-PC9
1
0
-1
0
6
12
18
24
30
36
42
48
54
60
Lag(seasons)

SSA reconstructed components (a-c)



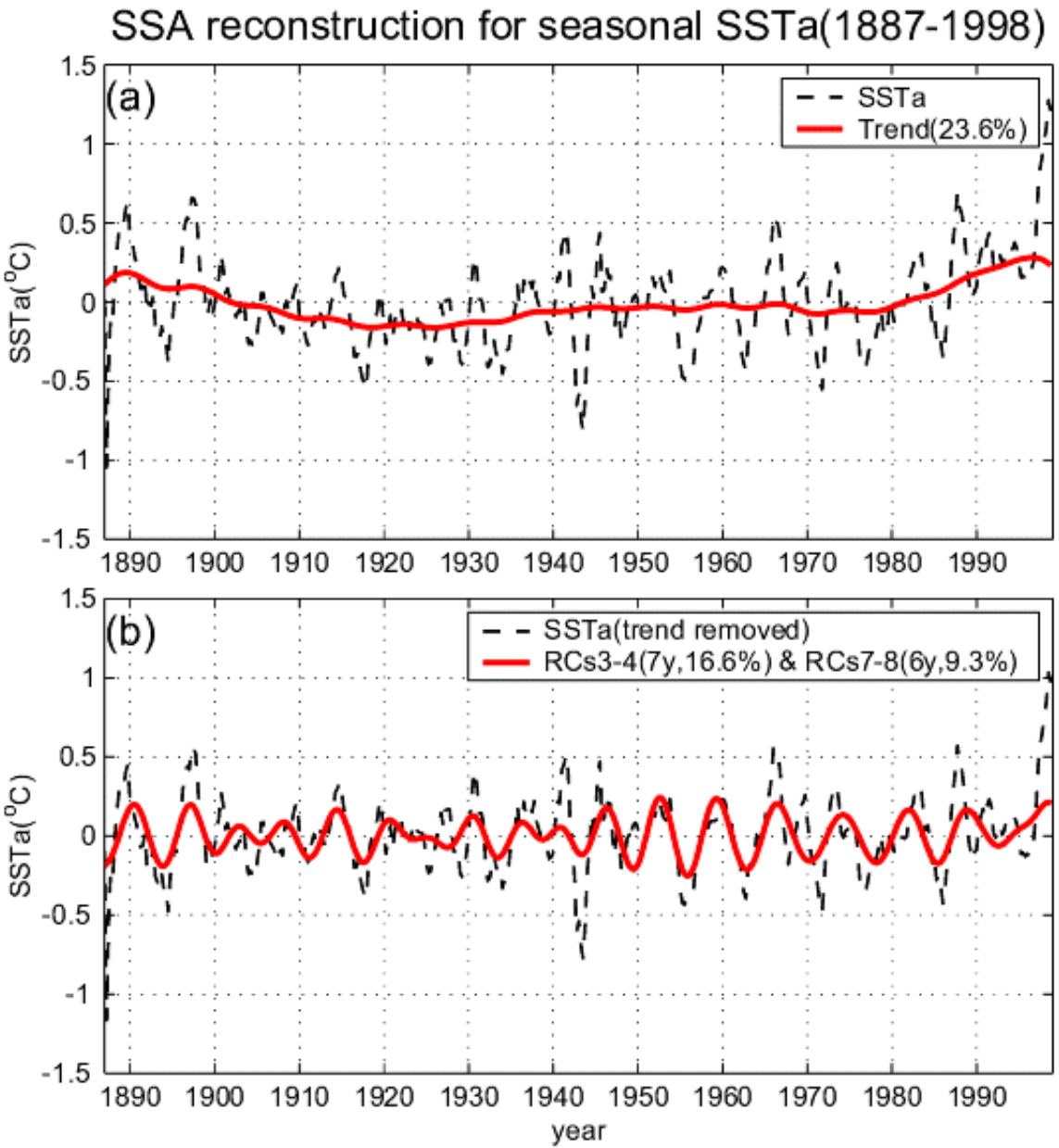
SSA reconstructed components (d-f)

Singular spectrum and fractional variance of CRU SST anomalies(1887-1998)

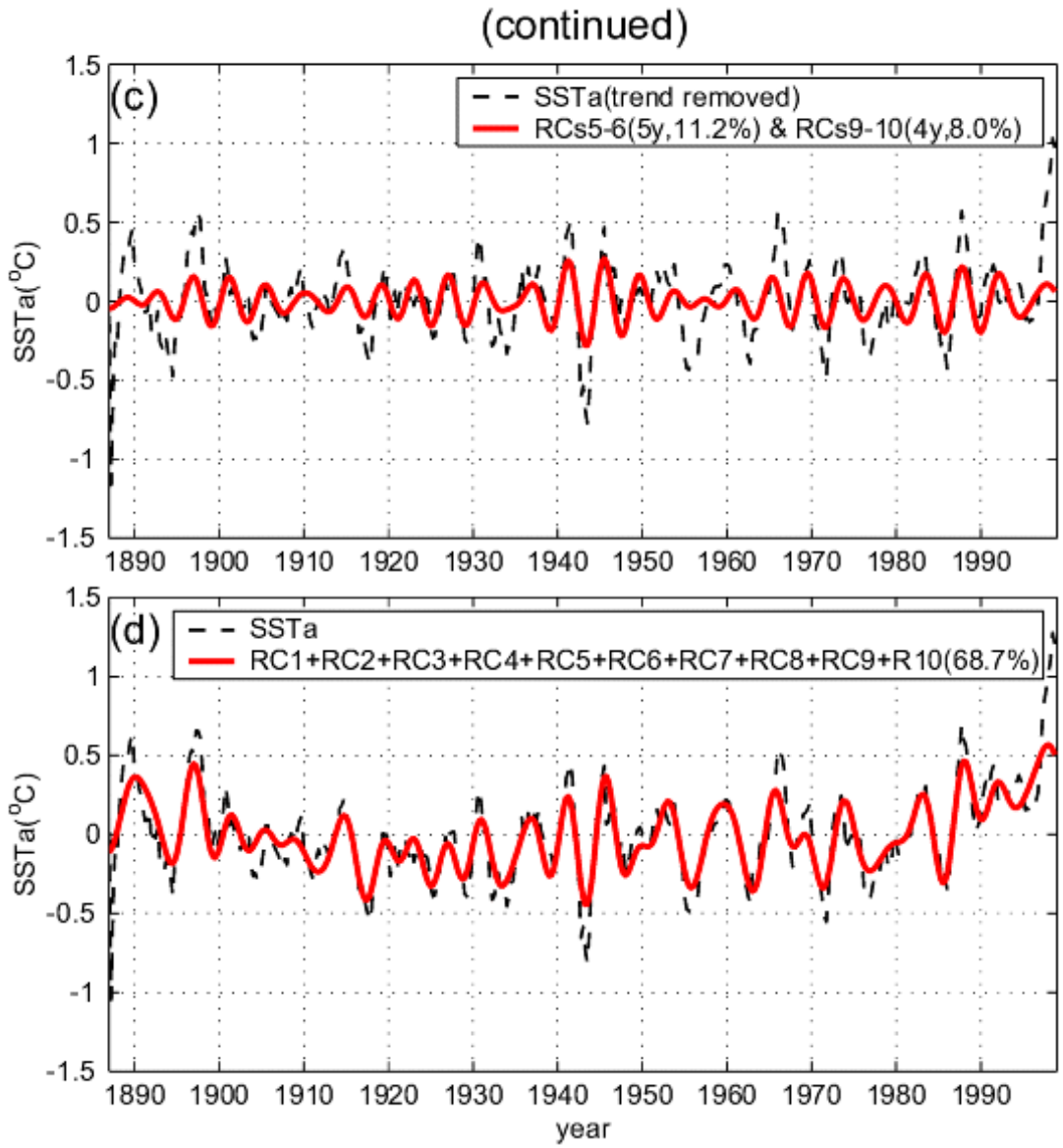


CRU Surface Temperature Anomalies (1856-1998)
SOURCE: Climatic Research Unit, Phil Jones
GRID: Global - 5 degree grid [lon=72, lat=36]

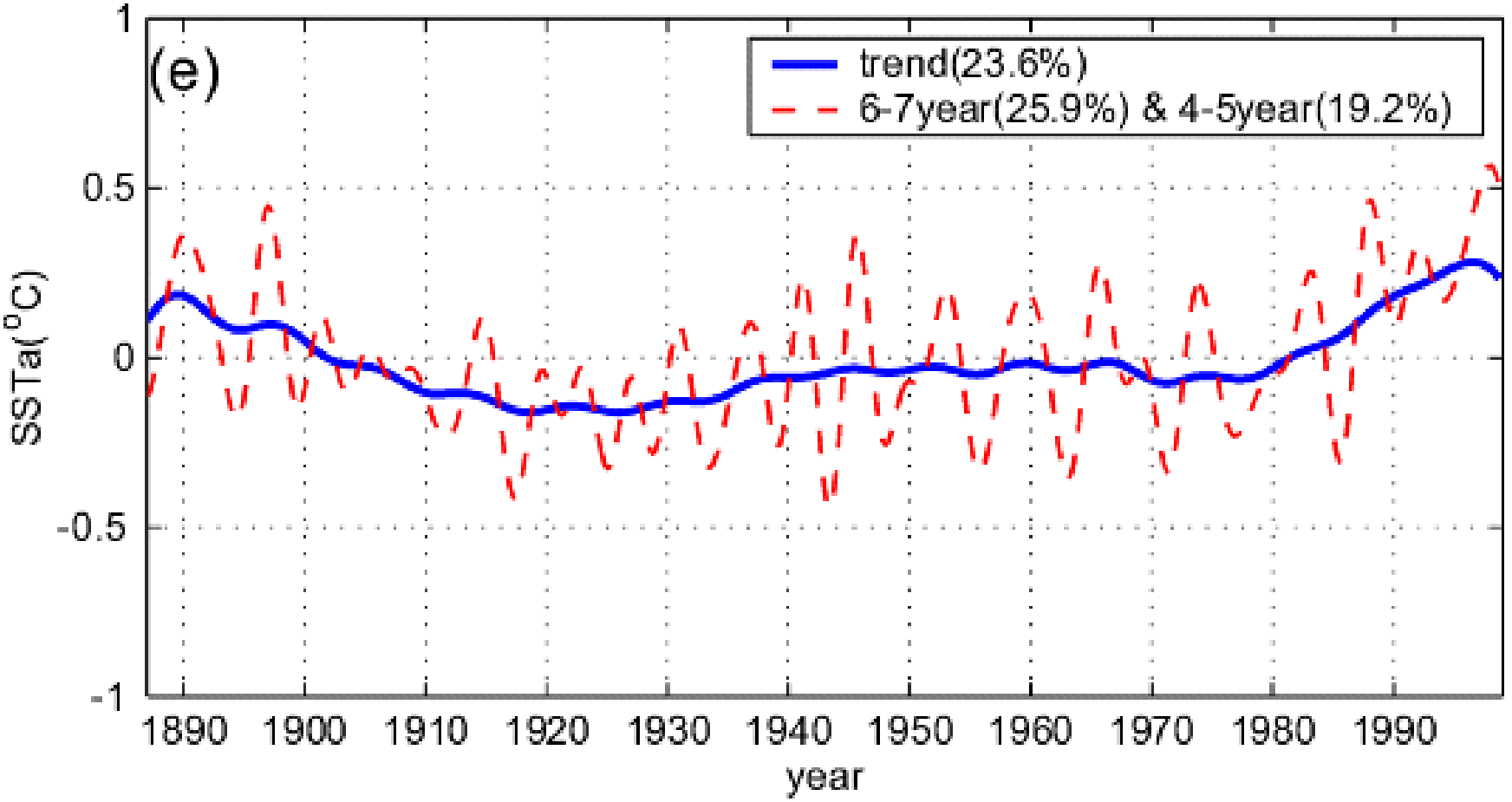
SSA reconstructed components (a-b)



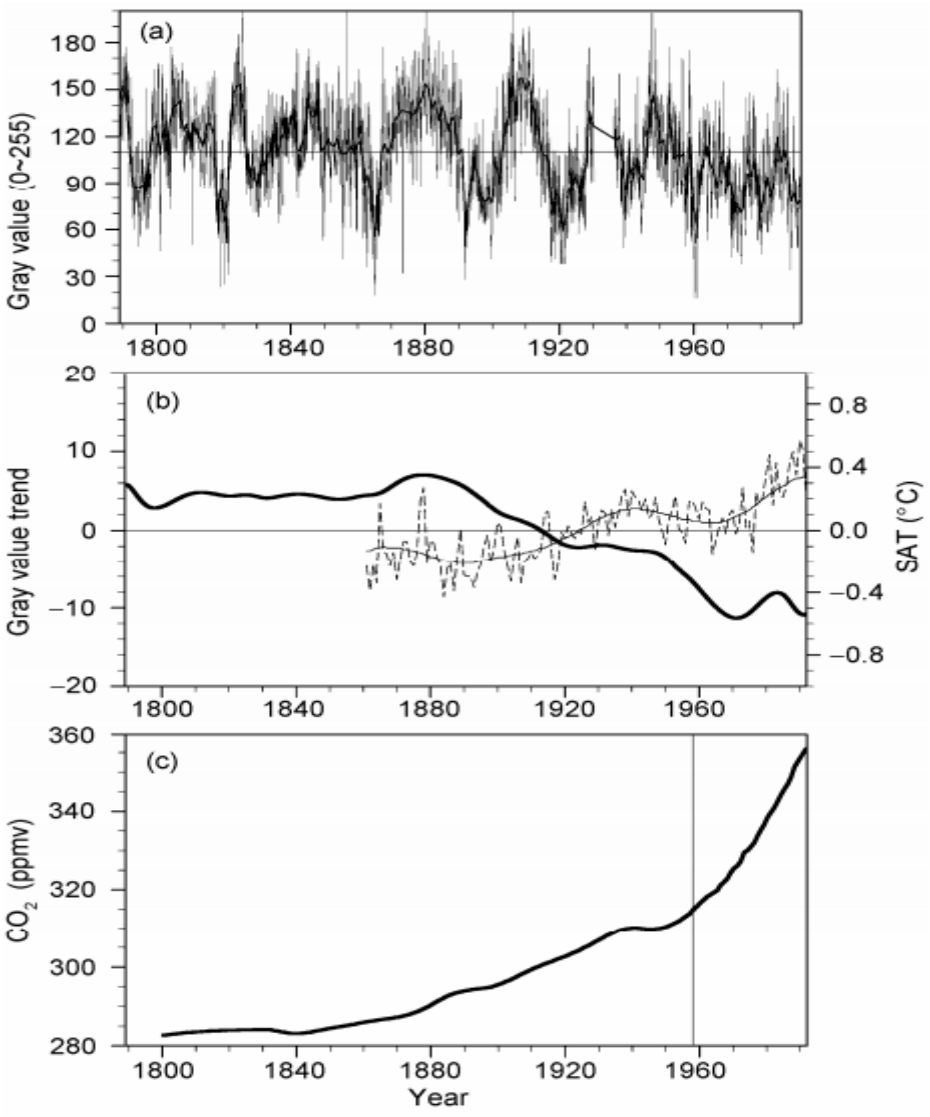
SSA reconstructed components (c-d)



SSA reconstructed components (e)



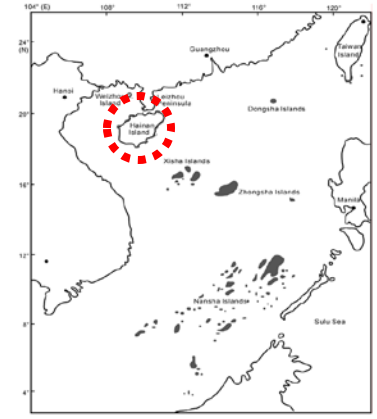
Secular trend of coral skeletal density in the SCS

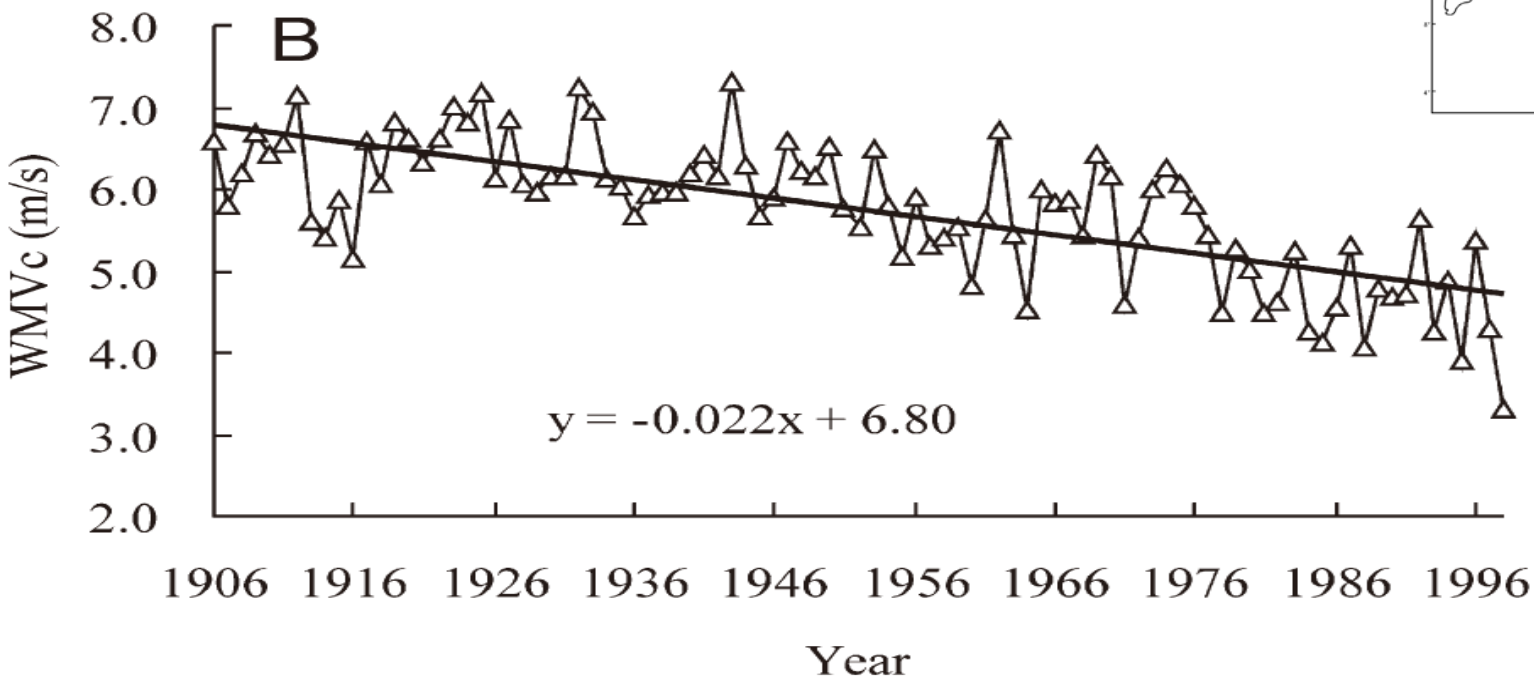


(Wang et al., 2010;)

- The gray values as the proxy index of coral skeleton density were few changes before 1880 (pre-industrial times) and decreased sharply from 1880 to 1920 and again after 1950.
- The gradually decreasing grey value secular trend since the late 19th century agrees remarkably well with the global warming and the increase in CO_2 concentrations in the atmosphere.
- The secular trend in this coral grey value record is a response to the anthropogenic climate change.

EA Winter monsoon velocity declining from 1906-1996: Hainan coral Sr/Ca records



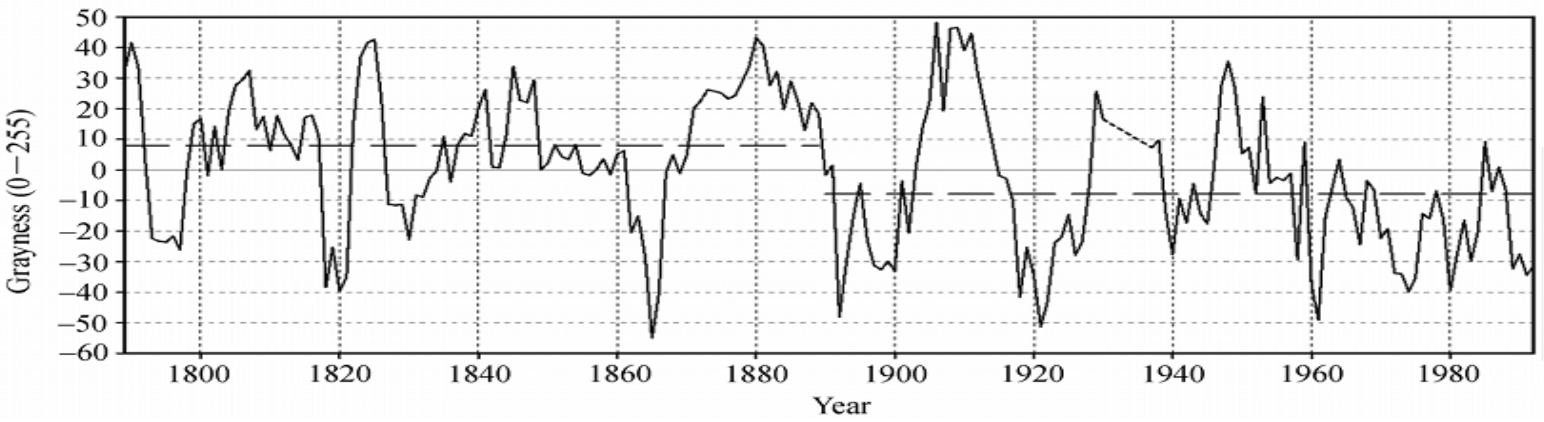


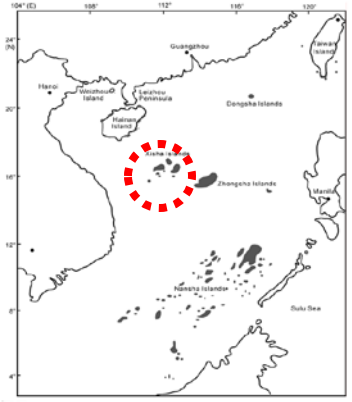
- The WMVc in the 20th century shows significant interannual and decadal variability with a trend of persistent decline.
- The WMVc has decreased significantly by about 30% from the early to the late of 20th century.

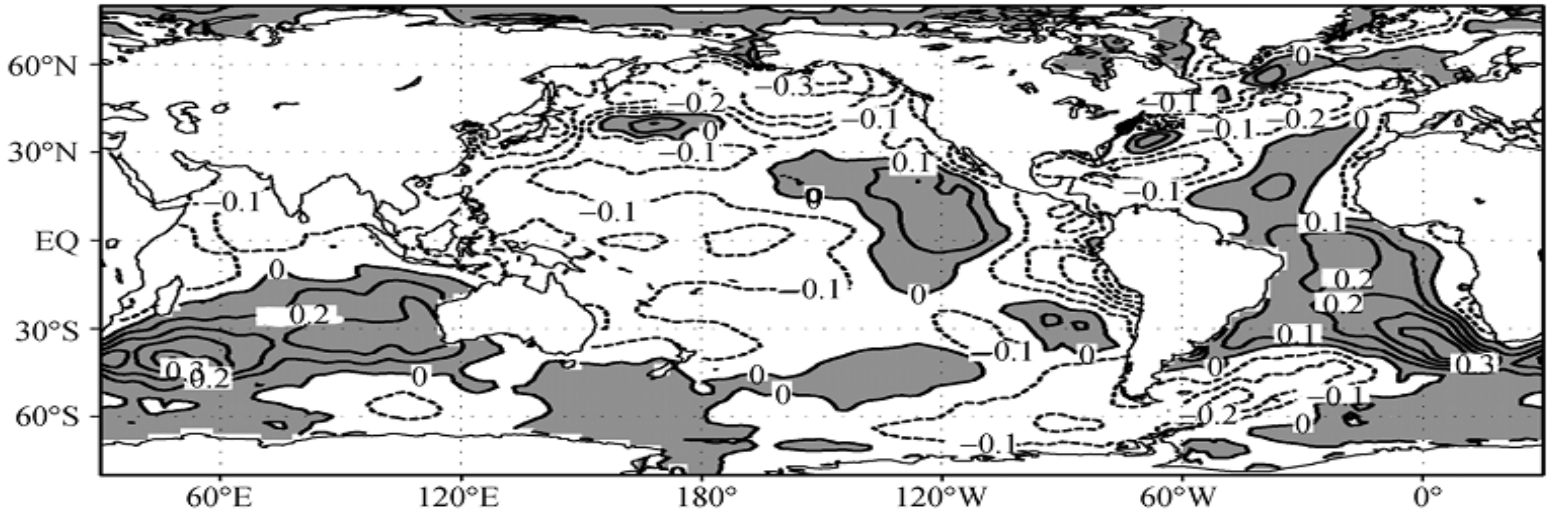
(Liu et al, 2008)

Regime shift of the climate

The coral grayness in northern South China Sea



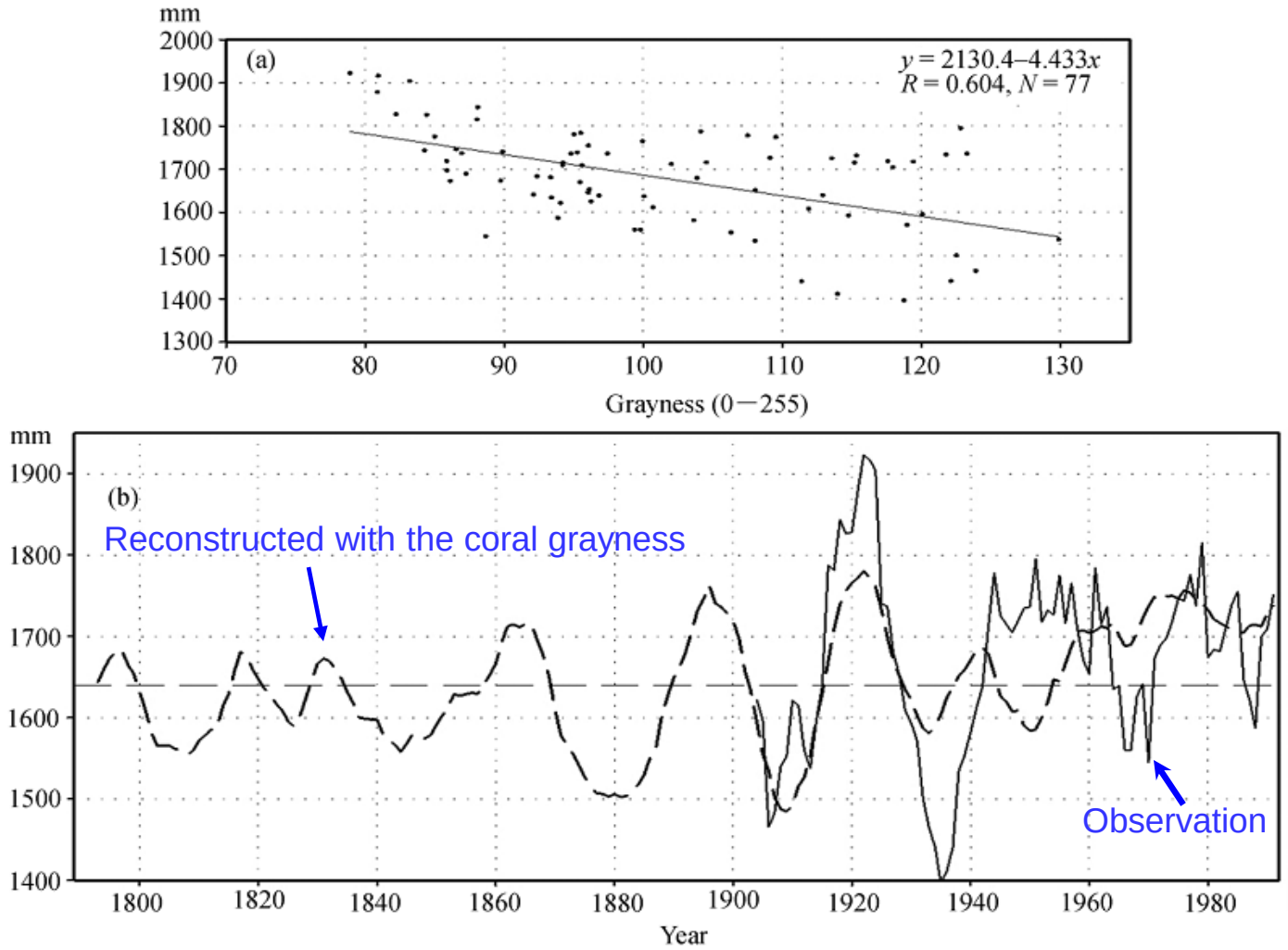




- 1889 was the year of abrupt change and the negatively anomalous sea temperature over large areas of SCS and adjacent regions is concomitant with the abrupt change of coral grayness in the SCS.

(Gu et al., 2006;)

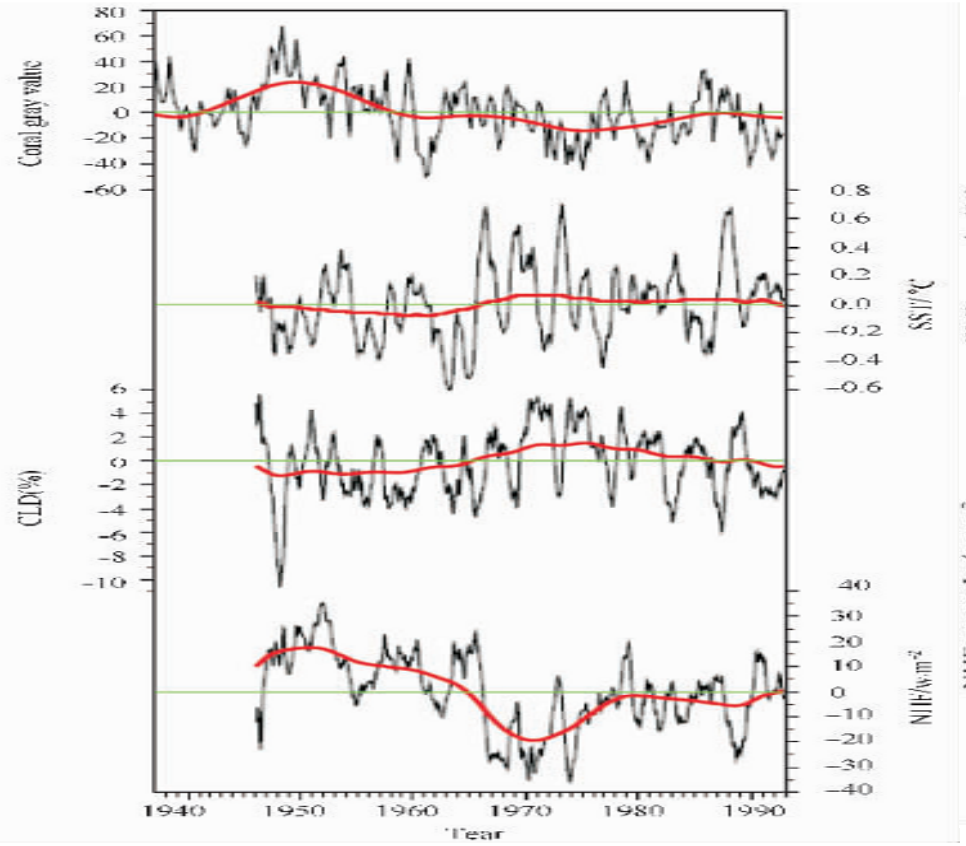
The variation of precipitation in south China as reconstructed from the grayness of coral

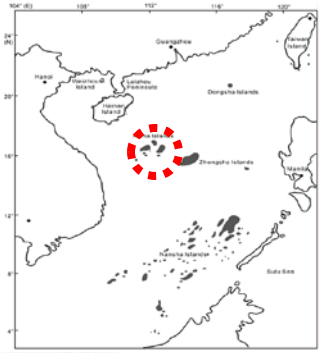


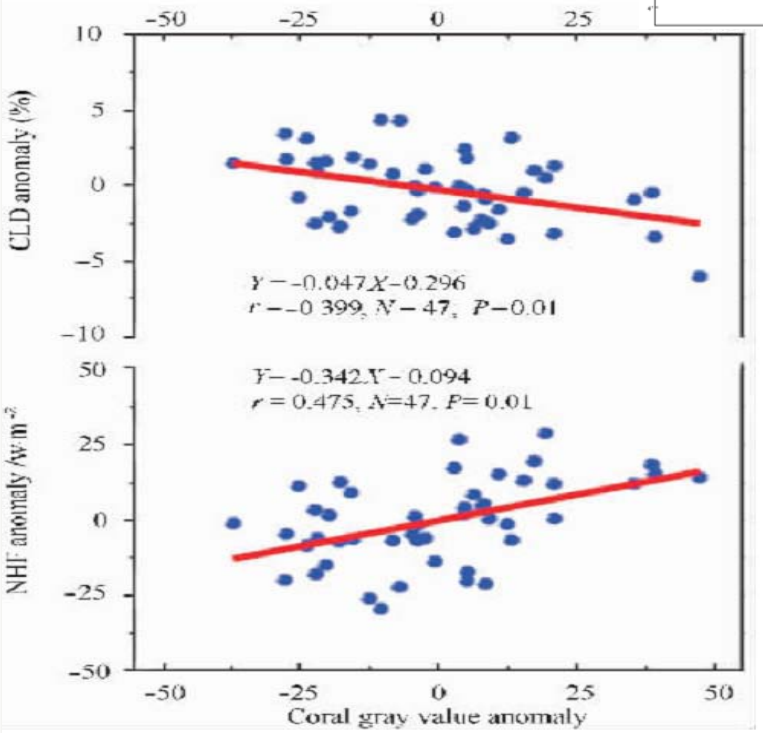
- The interdecadal variation as depicted by precipitation of Guangzhou is reliable, which is reconstructed with the coral grayness in SCS.

(Gu et al., 2006;)

Cloudiness regime shift during 1946~1992 recorded by coral in the South China Sea





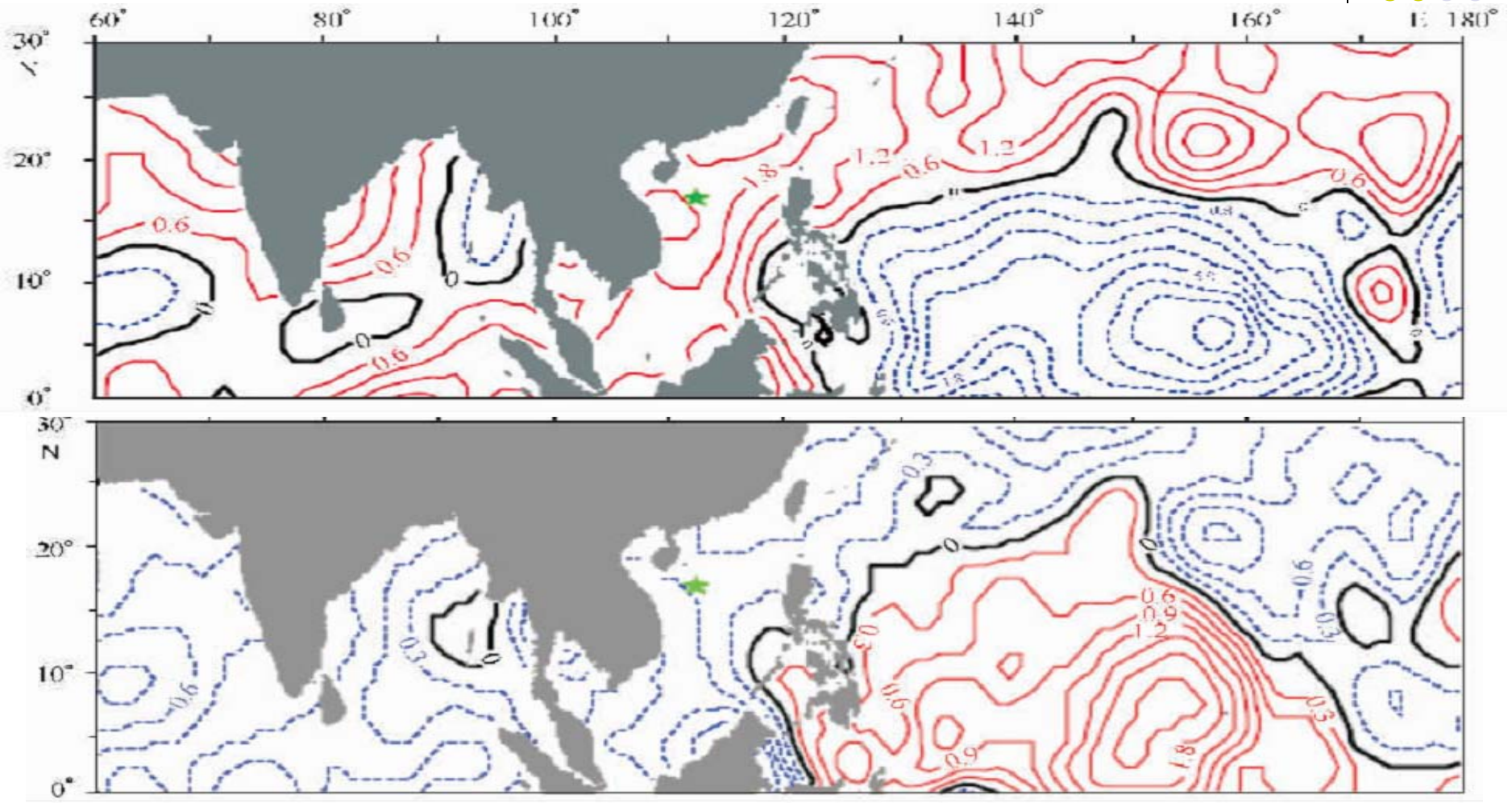


- From the observed trends of SST, CLD, NHF, it can be obviously detected that the regime shift, defined as a transition from one climatic state to another, occurred in the mid-1960s, which corresponds to the shift of coral gray value record.

- The coral gray value is more correlated to variations of cloudiness and net heat flux based on the correlation and regression between them.

(Gao et al., 2005;)

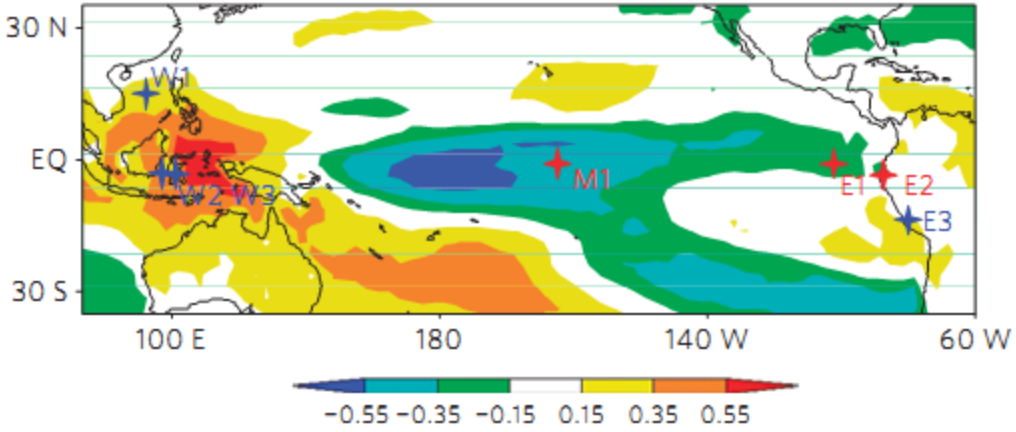
Relationship between Cloudiness and coral gray value

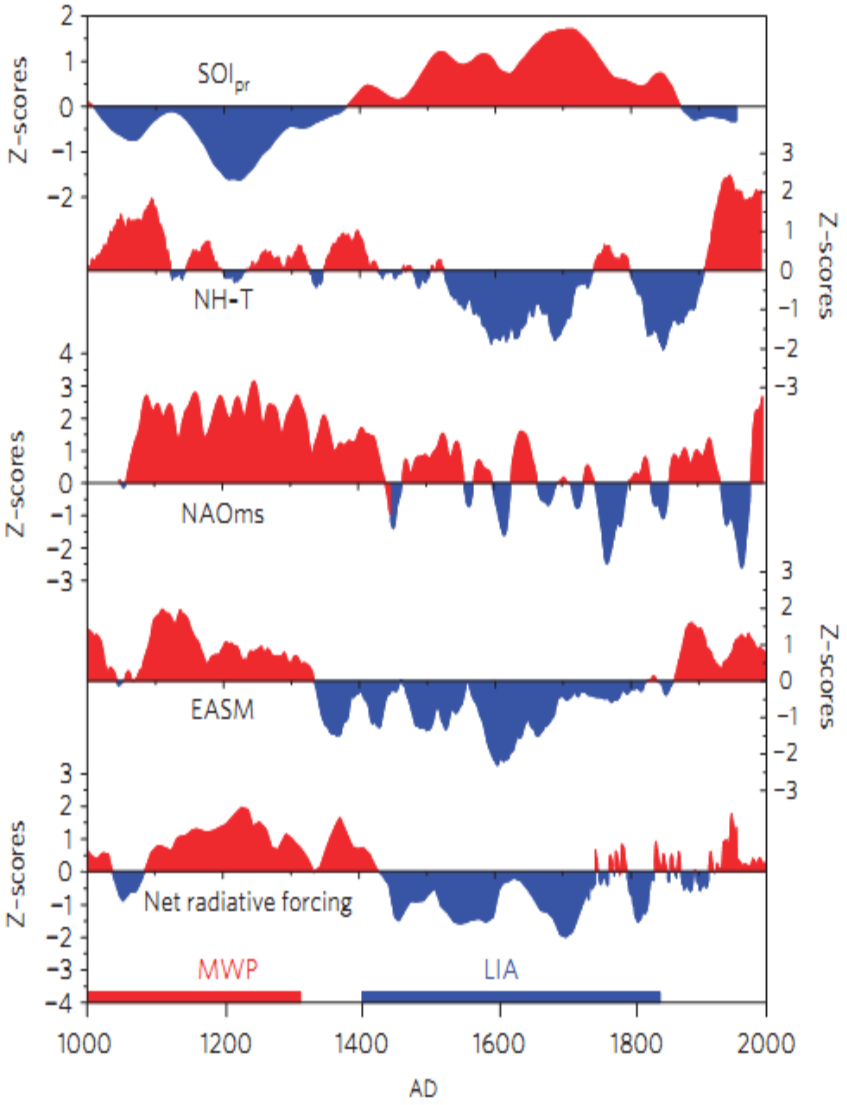


● The coral gray value record can be used as a reliable indicator to reflect the cloudiness regime shift in the whole SCS.

(Gao et al., 2005;)

A record of the Southern Oscillation Index for the past 2,000 years from precipitation proxies

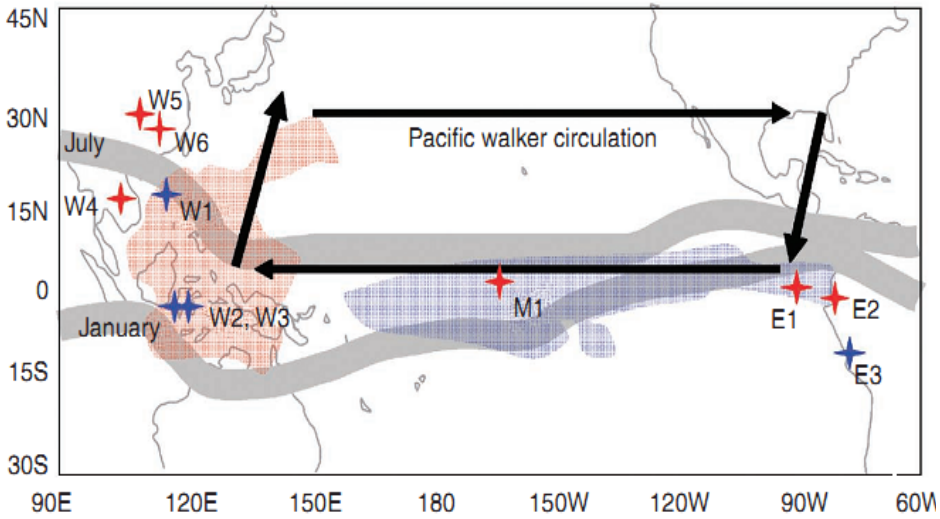


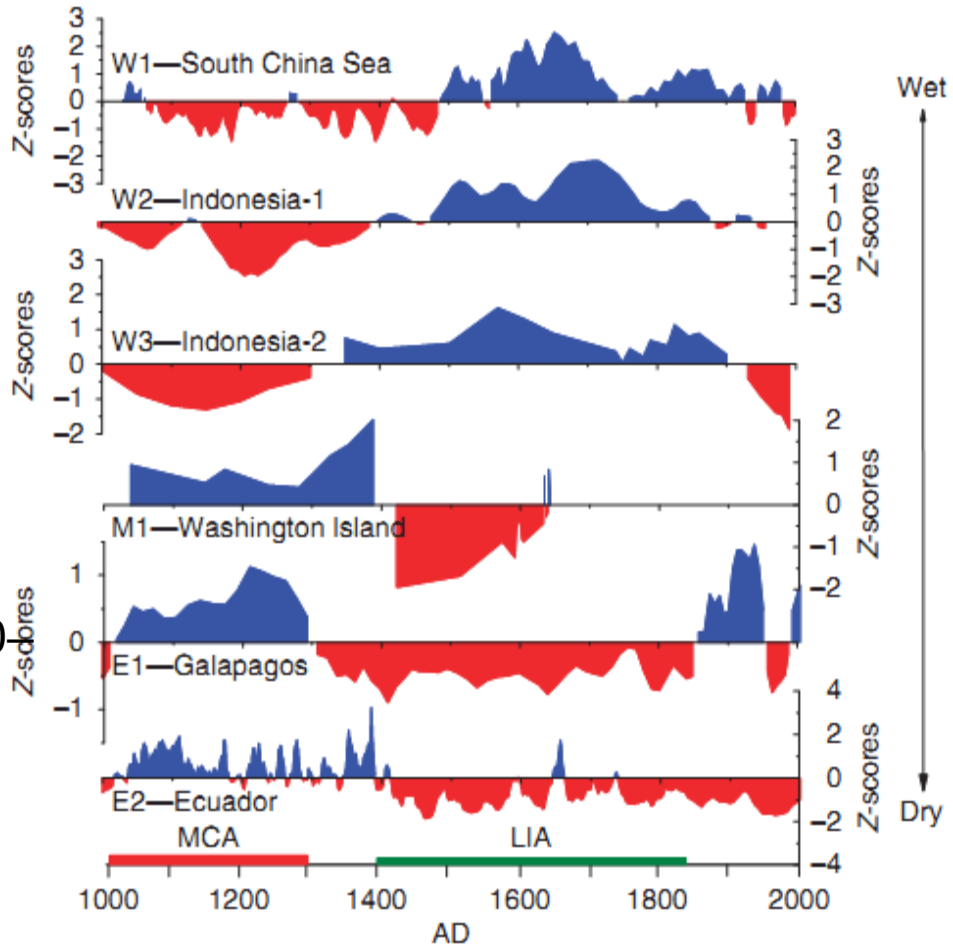


- Locations of hydrological records Correlations of monthly anomalies of precipitation (NCEP reanalysis2) with the SOI from January 1979 to December 2010.
- The Medieval Warm Period (AD 800–1300) was characterized by a negative index, which indicates more ElNiño-dominated conditions, whereas during the Little Ice Age (AD 1400–1850) more LaNiña-dominated conditions prevailed. The Southern Oscillation Index we derive is significantly correlated with reconstructions of solar irradiance, mean Northern Hemisphere temperature fluctuations.

(Yan et al, *Nature Geoscience*, 2011)

South China sea hydrological changes and Pacific Walker Circulation variations over the last millennium

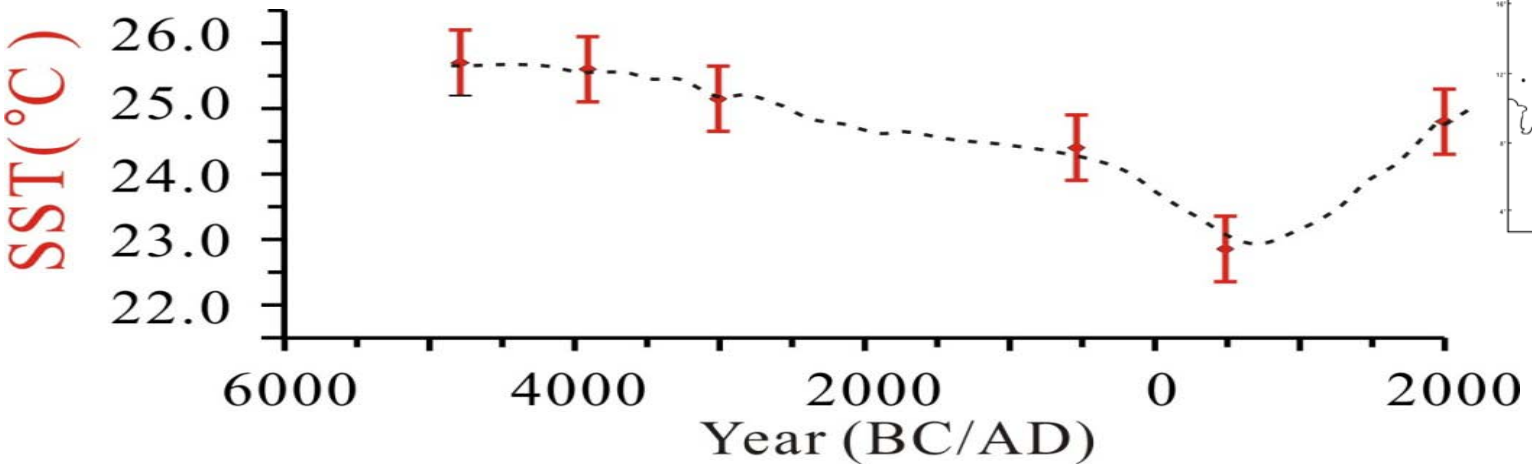




- The reconstructions indicate that this site received less precipitation during relatively warm periods, AD 1000–1400 and AD 1850–2000, compared with the cool period (AD 1400–1850).
- Including our new reconstructions in a synthesis of tropical Pacific records results in a spatial pattern of hydrologic variability that implicates the Pacific Walker Circulation (PWC).

(Yan et al, *Nat. Commun.*, 2011)

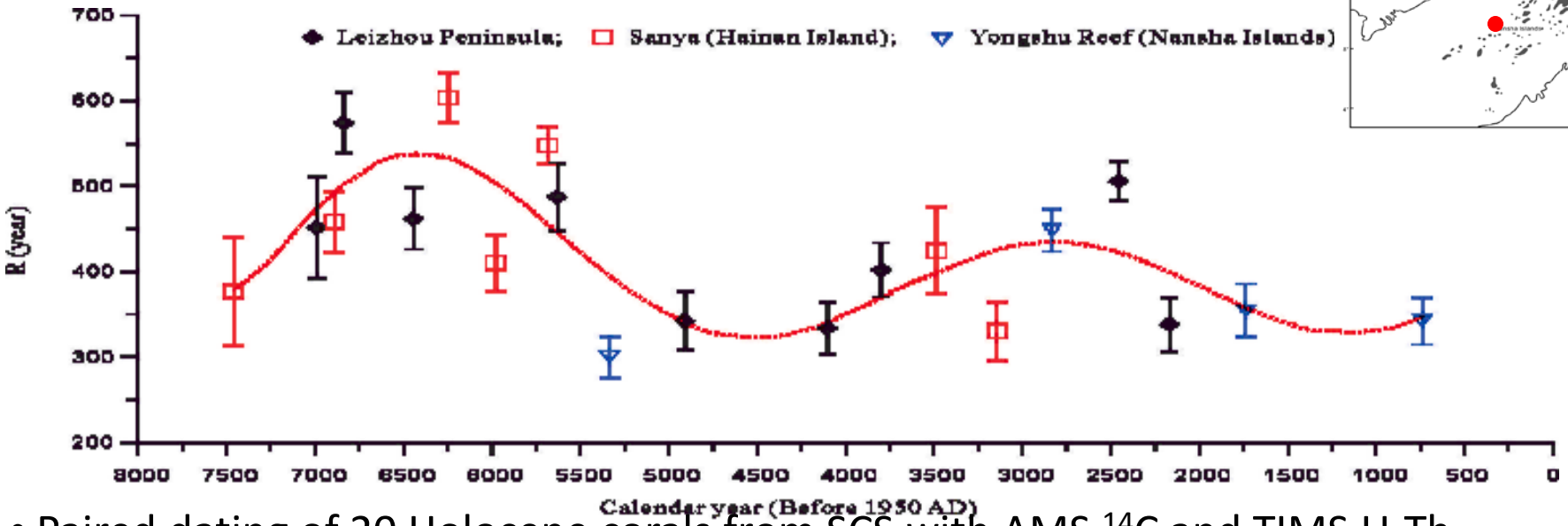
EA monsoon weakening over last 7000 years



- Sr/Ca of corals from Leizhou peninsula (northern SCS) revealed a general decreasing trend of SST from 6800 to 1500 years ago.
- SST decline is accompanied by a similar decrease in the amount of monsoon moisture transported out of SCS, resulting in a general decrease in the seawater $\delta^{18}O$ values.
- This decline/decrease indicates a general weakening of the East Asian summer monsoon.
- SST increased dramatically in recent time indicates the disturbance of anthropogenic greenhouse gases on the natural climatic trend in East Asian monsoon regime.

(Yu et al., *Glob Planet Change*, 2005)

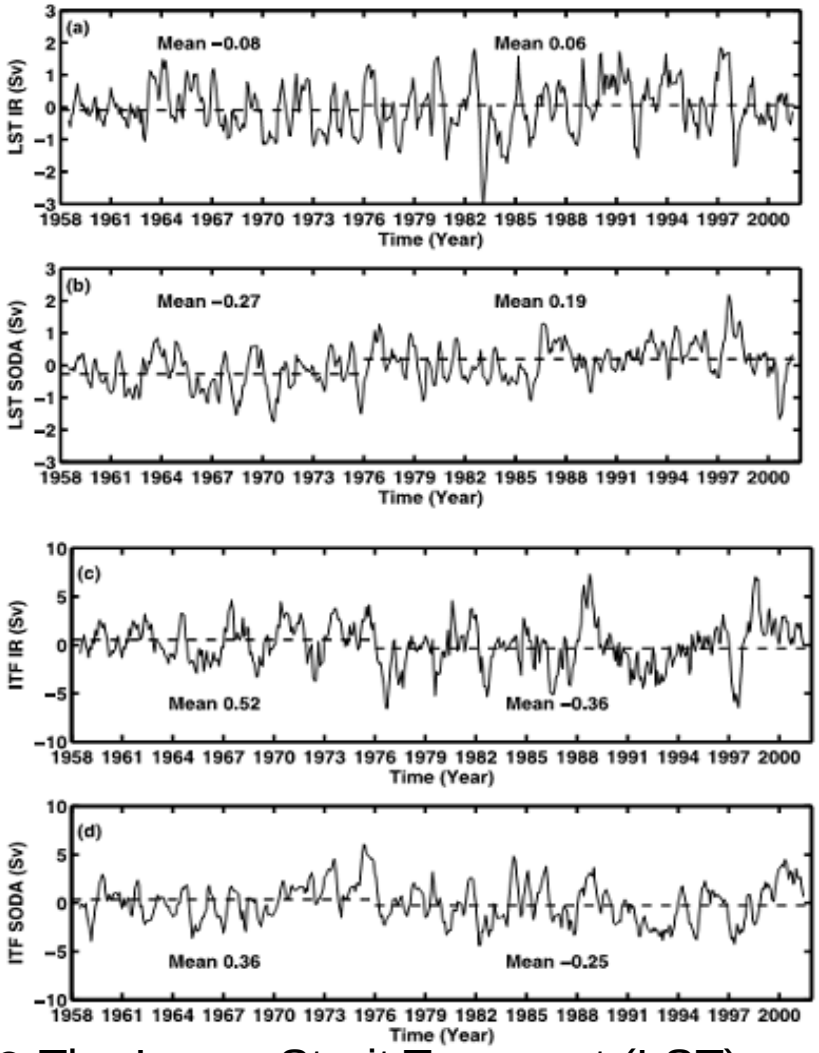
Millennial fluctuations of the EASM intensity over last 7500 years: evidence from carbon reservoir age (R)



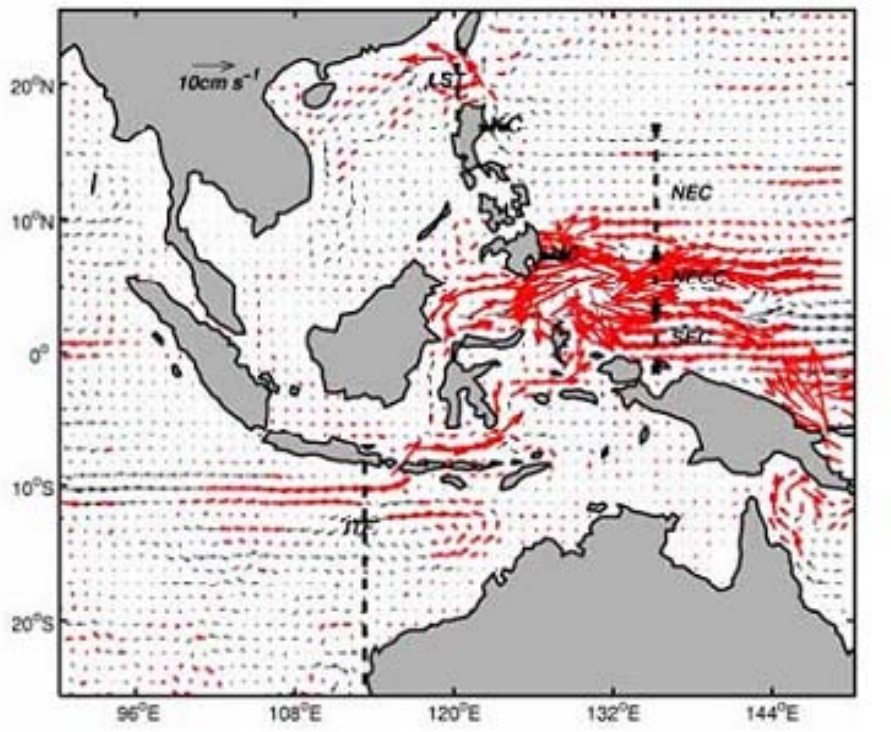
- Paired dating of 20 Holocene corals from SCS with AMS ^{14}C and TIMS U-Th techniques suggests that carbon reservoir ages (R)-controlled by EASM upwelling and NEC, show millennial scale fluctuations over the past 7500 years.
- The overall decreasing trend of R from 7500 cal year BP to present indicates the weakening of the East Asian summer monsoon intensity (and the strengthening of El Niño activity).
- The two plateaus at around ~7.5–5.6 and 3.5–2.5 cal ka BP are the result of the weakening of El Niño activity and anomalous intensification of the East Asian summer monsoon.

(Yu et al., *Paleoceanography*, 2010)

The 1976/77 Regime Shift of the Indonesian Throughflow and South China Sea Throughflow



● The Luzon Strait Transport (LST) and Indonesian Throughflow (ITF) transport.



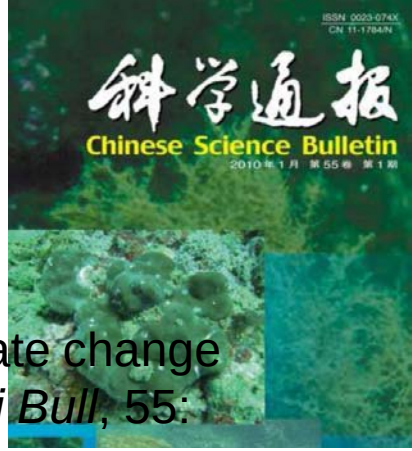
● Ocean circulation difference (1976–2001 minus 1958–1975) averaged in the upper 465 m.

(Liu et al, 2010)

Conclusion

- Corals have proven to be excellent archives in recording environmental history of tropical oceans over the past hundreds of thousands years over the South China Sea
- The trend from the two-century-long annual density of the coral over the northwestern SCS is in a good agreement with that of the global CO2 concentration. And EA Winter monsoon velocity declining from 1906-1996 according to Hainan coral Sr/Ca records.
- There is a century-scale abrupt change of coral grayness in the SCS at the end of the 1880s that changed from positive anomalies to negative anomalies, which is concomitant with the large-scale distribution of SST anomalies. Meanwhile, the cloudiness over the SCS exist a prominent regime shift in the mid-1960s, which can be successfully recorded by coral gray value.
- East Asian monsoon variations over last 7500 years-evidence from corals in the South China Sea.
- In Millennium time-scale, the corals well reflected the variability of Southern Oscillation Index and Pacific Walker Circulation
- Luzon Strait Transport (LST) increased but Indonesian Throughflow (ITF) transport decreased after 1975.

Related papers



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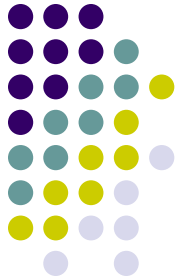

THANK YOU!